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Crossing the Technology Adoption Chasm: Implications for DoD

30 June 2008

by

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Abstract

DoD faces significant challenges in delivering promising new technologies to service members quickly and cost-effectively. To better understand DOD's technology adoption challenges, we review the technology diffusion literature to identify factors associated with successful and unsuccessful technology adoption processes, conduct case studies of DoD's advanced technology programs and propose a conceptual technology adoption model.

The literature review identifies three overarching factors reflecting the complexities of defense technology adoption: benefit-cost uncertainty, organizational externalities, and direct and indirect network externalities. Technology adoption clearly involves benefit and cost uncertainties. Organizational externalities arise because there are typically multiple stakeholders from different DoD constituencies. Direct and indirect network externalities reflect the joint and interrelated nature of defense technologies on the battlefield.

A closer look at one of DoD's advanced technology development programs indicates that success factors in this program generally parallel the results of the literature survey: the importance of benefit-cost uncertainty, management commitment (organizational externalities), technology champion (network externalities) and the prospects for future technology transfer (network externalities).

Finally, we present conceptual technology adoption models incorporating benefit-cost uncertainty, organizational externalities and network externalities. These models can explain the diffusion patterns observed in the defense department: no adoption, full adoption, and partial adoption/de-adoption.

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Executive Summary

The diffusion of a new private sector technology across a group of end-users is thought to follow a normally distributed “bell curve” pattern. Geoffrey Moore separates the Technology Adoption Lifecycle (TAL) into five end-user categories spread over this bell curve, based on the end-users’ characteristics and motivations (Moore, 1999). Starting from the left and earliest adopters, these categories include: the Innovators, the Early Adopters, the Early Majority, the Late Majority, and finally the Laggards.

The “Technology Adoption Chasm” refers to the gap in the TAL between the Early Adopters and the Early Majority and is sometimes referred to as the “Valley of Death” (VoD), particularly within the DoD. The chasm reflects the significant barriers confronted as technologies advance from the Early Adopters to the Early Majority phases. The problems occur when the relevant decision makers don’t recognize the distinct motivations and characteristics of the Early Majority compared to those of the Early Adopters. However, after crossing the chasm and seducing the Early Majority the new technology often embarks on a self-propagating path towards complete diffusion.

Technology transfer in the Department of Defense, getting new and improved weapon systems into the hands of our war-fighters, has been a persistent problem. For example, Advanced Concept Technology Demonstrations (ACTDs), more recently re-designated Joint Concept Technology Demonstrations (JCTDs), have been introduced to help facilitate the technology transfer process. ACTDs programs are designed to demonstrate commercial-off-the-shelf (COTS) technologies that can be quickly modified to serve joint service requirements. Unfortunately, ACTDs have experienced trouble crossing the technology adoption “chasm”.

This research examines the Technology Adoption Lifecycle and the Chasm that accompanies it, describing the Technology Adoption Lifecycle in a defense

context. Crossing the DoD's Technology Adoption Chasm involves aligning the incentives for each stakeholder in the decision-maker/buyer/end-user chain. To better understand DOD's technology adoption challenges, we review the academic technology diffusion literature to identify the factors associated with successful and unsuccessful technology adoption processes. The literature identifies a wide range of factors—many of which were inapplicable to the defense context and others of which, while applicable, provided no normative implications and thus were irrelevant from a policy perspective. Six factors seem particularly critical for a technology's ability to cross the Technology Adoption Chasm: resolving benefit-cost uncertainty; overcoming concerns about losing decision-making control; correcting misaligned incentives among different stakeholders within the organization; securing management commitment; identifying a clear technology champion; and ensuring a sufficiently large installed base of users for complementary goods and services.

These six factors are further consolidated into three overarching factors: benefit-cost uncertainty, organizational and other simple externalities, and direct and indirect network externalities. These three factors capture the complexities of the defense technology adoption process that involves multiple decision-makers (the joint staff that determines defense requirements, the service sponsors that manage the acquisition process and influence the resource allocation process, and the end-users or warfighters that actually adopt and use the new technology). Developing technologies clearly involve benefit and cost uncertainties. Organizational externalities arise when there are multiple stakeholders from different constituencies within DoD. Direct and indirect network externalities reflect the joint nature of many DoD technologies (fully exploiting their potential requires adoption beyond a single service or a single command within a service) and the interrelated nature of defense technologies on the battlefield (most defense technologies require significant complementary support goods and services and must be integrated with other defense technologies).

A closer look at the ACTD/JCTD program indicates that experience in this program is generally consistent with the factors identified in the literature survey: the importance of benefit-cost uncertainty, management commitment (organizational externalities), technology champion (network externalities) and expectations about the prospects for future technology transfer (network externalities). These were the primary significant variables in these cases, indicating that our literature search focused on the appropriate variables.

The research concludes by presenting conceptual technology adoption models that incorporated benefit-cost uncertainty, organizational externalities and network externalities. These models are capable of explaining the diffusion patterns observed in both the private sector and the defense department: no adoption, full adoption, partial adoption and partial adoption/de-adoption. To fully test these models requires an appropriately designed set of economic experiments. An experimental model was described to provide this validation. Future research will conduct the suggested economic experiments. If these models are validated, they can become the foundation for further experiments and simulations to explore policy options the defense department can consider to help defense technologies cross the defense Technology Adoption Chasm.

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Introduction

In the world of technology adoption, a chasm exists between the technology enthusiasts and the practical professionals of an industry who attempt to capture and leverage the benefits of new technologies for their field. In the private sector, a technology is considered to have crossed the chasm when it is on a self-sustaining path towards diffusion across the population of users. There is ample literature in the private sector about factors that help a new technology cross the chasm.

The public sector also tries to leverage benefits of new technologies but has its own set of challenges to overcome in this process. For example, consider the Department of Defense (DoD). Within the DoD, the Advanced Systems and Concepts Office (under the Office of Acquisition Technology and Logistics) sponsors 10 technology transition programs. One office in particular—the Joint Capability Technology Demonstration (JCTD) office (formerly the Advanced Concept Technology Demonstration (ACTD) program)—has the explicit goal of placing technologies into the hands of the warfighter in 2-4 years; it strives to accomplish this objective in a cooperative effort between the Joint Combatant Commanders and the funding Services.

The ACTD/JCTD program takes commercial off-the-shelf technologies that can be adapted to defense applications. The program demonstrates the technologies in defense applications and then attempts to insert them into the formal defense acquisition process. To enter the ACTD/JCTD program, the technologies need to secure one of the services as their funding and lifecycle sponsor.

While lofty in its temporal goals, the ACTD/JCTD office has its own unique transition challenges (GAO, 1998; 2002). The research presented in this report was motivated largely by the difficulties the ACTD/JCTD program has experienced in the technology transfer and adoption process. The program has had difficulty transferring technologies despite successful demonstrations. In part, the Naval

Postgraduate School (NPS) is helping to address this by developing business cases to augment the technology demonstrations. This research asks if there are other issues that might also facilitate technology transfer in the defense department.

As the researchers looked beyond the ACTD/JCTD program, we found more generic problems across DoD. Technologies such as NMCI (GAO, 2006b; Perkins, 2005), RFID (Solis, 2006; GAO, 2005) and Land Warrior (Shachtman, 2007) also have diffusion issues; they have been adopted by end-users, but they are less than successful in that diffusion. It appears that technology transfer, both within DoD and the private sector, follows at least four diffusion patterns: no adoption, partial adoption, complete adoption and partial adoption/de-adoption. We want to develop a model that can explain these paths for potentially cost-effective technologies. This research does not look specifically for ways to streamline the acquisition process; it looks at factors that inhibit military end-users from successfully adopting new technologies.

Specifically, this research explores the well-known Technology Adoption Lifecycle (TAL) and technology transfer literature to identify the factors contributing to the observed adoption patterns. This model is compared to case studies from the private sector and a detailed analysis of experience from the ACTD program to ensure consistency with experiential evidence. Finally, it outlines a model for future analysis using experimental economics to verify that the issues identified are consistent with the observed technology diffusion patterns, after which policy can be addressed in additional simulations and experiments.

The Technology Adoption Chasm

The Technology Adoption Lifecycle (TAL)

The diffusion of a new technology across a group of end-users is thought to follow a normally distributed “bell curve” pattern. Geoffrey Moore separates the Technology Adoption Lifecycle (TAL) into five end-user categories spread over this bell curve, based on the end-users’ characteristics and motivations (Moore, 1999). Starting from the left and earliest adopters, these categories include: the Innovators, the Early Adopters, the Early Majority, the Late Majority, and finally the Laggards.

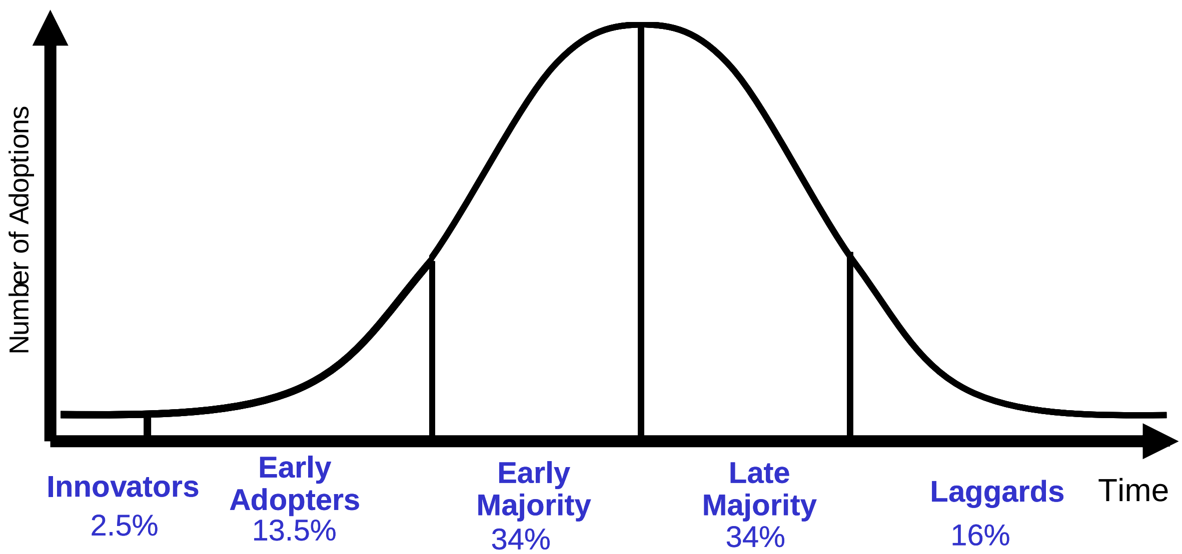

Figure 1. Technology Adoption Lifecycle
(Moore, 1999)

The Innovators are also known as Technology Enthusiasts. They are excited by a new technological break-through; they are not as concerned with monetary returns as they are with the potential for innovation. The Innovators want to experiment with the new technology as soon as possible to learn its potential. These end-users represent the segment below the second standard deviation, extending into the left tail of the curve.

The Early Adopters are also known as the Visionaries. These end-users see value for the new technology within their industry and want to capitalize on the savings or new capabilities before their competitors or colleagues. They are willing to risk technical immaturity, recognizing that not all aspects of the new technology have yet been worked out. These adopters are willing to risk embracing an immature industry standard, as the best technology has often not been developed or optimized for the industry. These end-users fill the section of the bell curve between the first and second standard deviations below the mean. These first two segments together—the Innovators and the Early Adopters—are referred to as the Early Market; the remaining segments—the Early Majority, Late Majority, and Laggards—are referred to as the Late Market (Moore, 1999).

Members of the Early Majority are also known as the Pragmatists. These end-users are much more conservative than the Early Adopters. They are receptive to new technology, but they are not as resolute as the first two groups and are highly influenced by their peers. The Early Majority is more conservative and risk-averse. Members of this group want to ensure that the new technology fits their organization's needs, has wide utility across their industry, and is a good and mature product for the job. They do not want to commit to an untested technology that may have imperfections reducing its efficiency or efficacy, or that is not the technology the competitive market will embrace (socially optimal). These end-users fill the bell curve from the first standard deviation below the mean to the mean.

The Late Majority is made up of Conservatives. These adopters value tradition over progress and resist discontinuous innovation (an innovation that changes processes or procedures and disrupts an organization). They won't commit to a new technology until they are certain technological and economic uncertainties have been resolved; they will wait until it is professionally uncomfortable in their industry to remain loyal to the old technology. These end-users fill the bell curve from the mean to the first standard deviation above the mean.

The final group is the Laggards, also known as the Skeptics. Its members will stubbornly resist the new technology until forced to change to stay in business or simply to function (Moore, 1999).

The Technology Adoption Chasm

The "Technology Adoption Chasm" refers to the gap in the TAL between the Early Adopters and the Early Majority and is sometimes referred to as the "Valley of Death" (VoD), particularly within the DoD. The chasm reflects the significant barriers confronted as technologies advance from the Early Adopters to the Early Majority phases. The problems occur when businesses and marketers don't recognize the distinct motivations and characteristics of the Early Majority compared to those of the Early Adopters. However, the new technology often embarks on a self-propagating path towards complete diffusion after crossing the chasm and seducing the Early Majority.

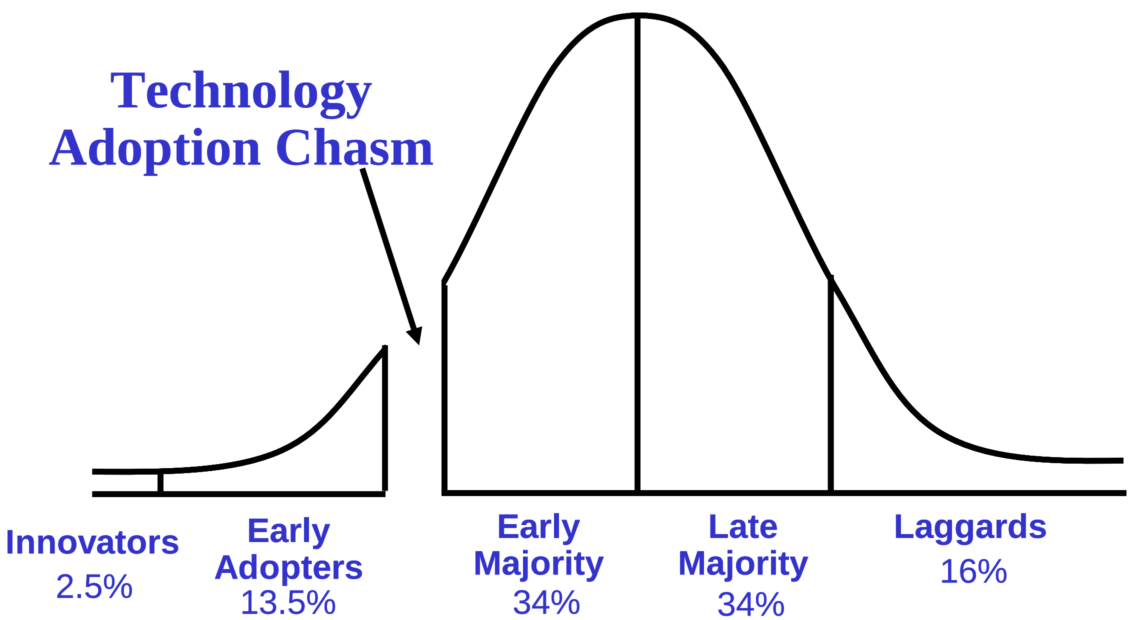

Figure 2. Technology Adoption Chasm
(Moore, 1999)

There are fundamental differences between the Early Adopters (Visionaries) and the Early Majority (Pragmatists) that present a significant challenge for technologies crossing the adoption chasm. In general, members of the Early Majority have a stronger interest in the net benefits the technology offers their industry; the Early Adopters are more interested in experimenting with new technologies and innovations despite the uncertainties involved. This difference in priorities contributes to the observation that the Early Majority is populated by pragmatists rather than technology enthusiasts or visionaries.

Secondly, members of the pragmatic Early Majority value their peers' opinions and experiences far more than their own desire to remain on the cutting edge of technology. In other words, they are a self-referencing group (Moore, 1999). To break into this end-user segment, a product needs to secure Early Majority supporters who can recommend it to their peers. This creates a Catch-22: How can one secure Early Majority supporters if those supporters won't adopt without Early Majority peers to recommend the product? In contrast, the visionary Early Adopters are anxious to be amongst the first within their industry to embrace a new technology.

Thirdly, pragmatists are more acutely aware of the existing industry infrastructure and are wary of discontinuous innovations that would disrupt operations and productivity; visionaries are less respectful of established standards and infrastructure—they are excited about new technology and eager to adopt it regardless of incompatibility with existing infrastructure, disruptions to operations, or uncertainty regarding technological or economic performance.

Finally, the Early Majority thoroughly investigates the technological and economic uncertainties surrounding a new technology. Its members want to validate its overall value to the industry as well as the feasibility that their companies can capture that value before committing to the new technology for the long haul. The Visionaries are not so calculated and are more likely to shift to the next new

technology when it comes out, disrupting their production processes. They are not as loyal or committed to the status quo as the Early Majority (Moore, 1999).

As a technology crosses the Chasm, it has exploited most of the technology visionaries in the market and notably has trouble attracting new customers. The Pragmatists are not yet comfortable committing to the new technology because there aren't enough trusted references within their peer group recommending the new technology (Moore, 1999). The challenge for the technology is to find a way to break into the Early Majority and cross the Valley of Death (VoD).

A technology faces several possible outcomes while it loiters in the VoD. The technology may cross the VoD and continue on a self-sustaining path toward diffusion; technology diffusion may stall after only exhibiting partial diffusion within the industry (in other words, the industry could continue to maintain dual technologies); or finally, the industry might de-adopt the technology if the Early Market alone is insufficient to support the new technology. Considering this, any model of technology diffusion must be consistent with at least four diffusion patterns: no adoption, partial adoption, complete adoption and partial adoption/de-adoption.

The Technology Adoption Chasm in the Department of Defense

To better understand DoD's Technology Adoption Chasm, it helps to first understand its defense acquisition policies and procedures. There are three decision-making systems within the DoD acquisition process: the requirements process embodied in the Joint Capabilities Integration and Development System (JCIDS); the Planning, Programming, Budgeting and Execution (PPBE) process; and the Defense Acquisition System. The Joint Capabilities Integration and Development System (JCIDS) is the DoD process for defining DoD's acquisition requirements. Authority for the JCIDS process resides within the Joint Chiefs of Staff, as articulated by the *Chairman of the Joint Chiefs of Staff Instruction CJCSI 3170.01F*:

> The primary objective of the JCIDS process is to ensure the joint war-fighter receives the capabilities required to successfully execute the missions assigned to them. [...] The requirements process supports the acquisition process by providing validated capabilities and associated performance criteria to be used as a basis for acquiring the right weapon systems. (US CJCS, 2007, p. 2)

It replaces the pre-existing service-specific requirements-identification processes to reduce redundancies and gaps that might persist in a more decentralized system.

The PPBE process matches resources (money) with requirements, under the guidance and direction of several defense documents, including the *National Security Strategy*. This budget management process involves three years' budgets at any one time: it executes the current year's budget; it reviews and approves next year's budget, and it formulates the following year's budget for submission. The commands (the warfighters or the end-users) submit budget requests based on their needs. These requests are reviewed, modified and approved up through the military chain of command, to the Office of Management and Budget (OMB), Congress, and finally the President. The decision-making chain tries to predict what will be needed two to three years out and to balance priorities across all end-users.

The Defense Acquisition System is the management process by which the military buys weapons and information systems for the Department of Defense. The Defense Acquisition System's mission is to "manage the nation's investment in technology, programs, and product support necessary to achieve the National Security Strategy and support the United States Armed Forces" (DAU, 2004, p. 1). Its objective is to "acquire quality products that satisfy user needs with measurable improvements to mission capability and operational support, in a timely manner, and at a fair and reasonable price" (DAU, 2004).

The Defense Acquisition System is primarily governed by *DoD Directive (DoDD) 5000.1, The Defense Acquisition System*—which articulates the policies and principles that govern the acquisition system, and *DoD Instruction (DoDI) 5000.2, Operation of the Defense Acquisition System*—which outlines the management

framework that executes the policies and principles in *DoDD 5000.1*. The management framework tracks an acquisition program through its significant milestones (as the program proceeds from inception to the end of its lifecycle, each phase has its own reporting requirements (DAU, 2004)).

The traditional JCIDS, PPBE and DoD Acquisition processes are comprehensive and thoughtful, looking years into the future. They are long-term acquisition planning tools. However, DoD has faced increasing timelines to transition new technology from conception to utilization as defense technology has become more complex (GAO, 2006a; Sullivan, 2005). With technology evolving at a rapid rate, our ability to transition mature or emerging technologies to the operational forces is hampered by our inability to quickly plan, program and execute funds to meet rapidly changing requirements (Office of the Deputy Under Secretary of Defense (AS&C), 2004b).

Programmatic flexibility is critically important to technologically intensive programs, such as the ACTD/JCTD program. This program matches significant military needs with commercial off-the-shelf (COTS) technology development programs, focusing on joint military applications. This need is usually provided by the operational warfighting community (JCS, CINCs, Service operational organizations). The initial requirements and design reflect current COTS technological capabilities, but provisions are included to promote evolutionary improvements. The ACTD/JCTD process integrates mature COTS technologies into an innovative military capability, allowing decision-makers to fully understand the new operational potential before making an acquisition decision (Office of the Deputy Under Secretary of Defense for Advanced Systems & Concepts (AS&C), 2004a).

The ACTD/JCTD program meets this objective by developing prototypes of the proposed technology or capability and providing those prototypes to the warfighter for evaluation. The warfighter develops operational concepts to fully exploit the proposed capability and then assesses the resulting military utility in

realistic military exercises (Office of the Deputy Under Secretary of Defense (AS&C), 2004a).

The Deputy Under Secretary of Defense (Advanced Systems & Concepts) (DUSD(AS&C)) has oversight responsibility for the ACTD/JCTD program. He is responsible for developing and issuing guidance regarding the ACTD/JCTD program, for evaluating candidates and approving new ACTDs/JCTDs. In addition, every ACTD/JCTD requires active participation of a sponsor or user organization (COCOM or warfighter), in partnership with a service sponsor serving as the technical development manager (Defense Acquisition University, 2006) This creates a triad of critical stakeholders: DUSD(AS&C) oversees the early development process; the service sponsor serves as technical manager and ultimately chooses whether to field the new technology; the COCOMS or warfighters provide input to the development process and are the ultimate system users.

When an ACTD/JCTD is approved, the Deputy Under Secretary of Defense (AS&C) also approves the associated development funding, including any supplemental funding provided by the OSD. The Technical Manager (TM) from the sponsoring lead service executes these funds (Mol, 1998). The lead service must obtain funding for the subsequent ACTD/JCTD acquisition through the Planning Program and Budgeting System (PPBS), as with traditional acquisition programs.

While traditional acquisition programs are fully funded in the Future Years Defense Plan (FYDP), ACTD/JCTD programs are not required to include funding in the FYDP for post-ACTD/JCTD activity (development, full-rate production, or purchase of additional quantities of commercial items) until the ACTD demonstrates its military utility (Office of the Deputy Under Secretary of Defense (AS&C), 2004b). At first glance, excluding additional research and development (R&D) or acquisition funding from the FYDP may appeal to the Services and the OSD in a fiscally constrained environment. However, it creates problems as ACTD/JCTD technologies transition to acquisition programs; they must compete for scarce service-level funds with programs already established in the FYDP (Mol, 1998).

The lack of programmed funding creates a significant challenge that must be addressed during the transition effort.

As a result, innovative defense technologies crossing the Technology Adoption Chasm face several technology adoption challenges that require coordination across a complex set of stakeholders. The decision-maker choosing new technologies in which to invest, the service sponsor actually purchasing the technology and the technology's end-user are typically different stakeholders in the defense sector, as pictured in Figure 3 below. The decision-maker/buyer/end-user chain is more decentralized in the public sector than is typical in the private sector. While the goal of crossing the chasm is the same for these two sectors—placing the new technology on a self-propagating path towards total diffusion across the defense department—the momentum for getting technology to the end-users is more typically catalyzed by a push from the department leaders and technology enthusiasts. Successfully crossing the DoD Adoption Chasm requires aligning the incentives for all stakeholders and to specifically engage the end-users so that they "pull" the new technology over the chasm.

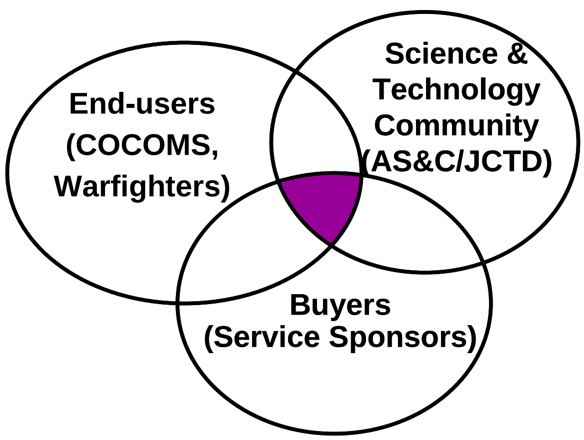

Figure 3. DoD Technology Adoption Stakeholders

To better understand the defense technology adoption problem, with particular emphasis on ACTD/JCTD program, this research will examine the academic technology transfer literature as well as the specific experiences of

ACTD/JCTD projects. The results of this literature review and empirical DoD experience will be used to develop a technology adoption model that is consistent with the transition patterns observed in DoD.

Literature Review

There is an extensive body of academic literature addressing innovation and technology transfer. (For a general discussion see Rogers, 1995.) This literature can be grouped across several dimensions: by industry focus (e.g., agriculture, health care, organizational, information technology, meta-analysis, etc.), locus of interest (individual adopter characteristics, technology characteristics, industry characteristics, adoption environment, information dissemination mechanism, etc.), methodology/analytical approach (econometric, survey/questionnaire, cost/benefit analysis, case study, etc.), type of innovation (administrative versus technical, incremental versus radical, etc.) and stage of the technology transfer process (innovators, early adopters, early majority, etc.).

Our literature survey included studies covering all dimensions of this spectrum. In addition, we specifically included studies that addressed technology adoption and de-adoption, as there is ample evidence of both in DoD. The goal is to identify factors that significantly affect technology diffusion—more specifically, factors that are relevant to DoD's experience. The ultimate goal is to develop a technology diffusion model that can replicate the technology transition patterns experienced in DoD. More specifically, we are interested in a defense technology adoption model that captures technology transition factors that can be influenced by DoD policy. (See Appendix A for a summary of the technology, locus of interest, methodology and significant/insignificant variables of these studies; the meta-analyses are not included in the literature review. See Appendix 2 for a summary of the articles surveyed for this research; bolded items are discussed in more detail below.)

Four case studies are examined more closely below (those in bold-faced type above), each highlighting the critical issues found to affect end-user adoption. CASE is computer-aided software engineering that was introduced in the late 1980s but was not ultimately adopted. Health Technology Assessments (HTAs) were a

health care management technology that met resistance in its diffusion. Radio Frequency Identification (RFID) is an on-going case of adoption that runs somewhat parallel to DoD's RFID adoption. Finally, the classic case of the QWERTY keyboard illustrates several of the critical end-user issues discovered in this analysis.[1]

Computer-aided Software Engineering (CASE)

Computer-aided software engineering (CASE) was expected to improve productivity by automating the lifecycle processes of the computer software that companies uses to run their businesses. A Management Information Systems (MIS) organization that was adopting CASE agreed to participate in a study of its effectiveness. The company had 100,000 employees and $9 billion in annual sales at the time (circa 1989). Its payroll included around 280 professional employees, and it funded a $12 million development budget. CASE implementation was considered a failure, and Norman, Corbitt, Butler and McElroy (1989) investigated why.

Typically, a company's software engineers improve their own systems—making this an interesting technology adoption case. CASE would replace the people that managed the company's internal software. In other words, these software engineers would have to adopt a technology that encroached on their territory of systems improvement, potentially making their engineering skills obsolete. The implementation was problematic because the software engineers at the MIS organization could not see the benefits of adopting the technology.

The software engineers needed to clearly see the benefits of this technology to reconcile themselves to adopting it. The technology would free the engineers from mundane computing tasks, allowing them to focus on larger, more critical problems. The engineers' willingness to adopt CASE was limited because they didn't see the potential for using their skills in more creative/constructive, less

[1] For further discussion of these case studies see Schang, 2007, pp. 63-74.

mundane ways; instead, they saw the technology as removing some of their autonomy and control (giving it to the CASE technology). The software engineers didn't recognize that their company needed this technological innovation to remain viable; they, therefore, resisted the adoption.

In addition, there was the noticeable absence of both a CASE technology champion and management commitment in the MIS organization. These deficiencies were cited critical factors in its failure to diffuse throughout the organization. The software engineers did not have a highly visible and well-respected advocate for the controversial technology they were being asked to implement; as a result, they questioned management's commitment (Norman et al., 1989).

Thus, CASE's failure to diffuse reflects the users' (software engineers') inability to see the technology's benefits, their fear of losing control to CASE, their lack of situational awareness regarding industry pressures and how CASE could help the company's profitability, their perception that management was not committed to the adoption and the distinct absence of a technology champion or management commitment for CASE.

Health Technology Assessments (HTA)

Health Technology Assessments help "improve decision-making about the diffusion and use of health technology" (Drummond & Weatherly, 2000, p. 1). They involve an iterative process that uses "synthesis and implementation" as a critical step in the Technology Assessment Iterative Loop (TAIL). This Loop seeks to exploit technology to improve medical practice, including reducing inappropriate or inefficient treatment (Drummond & Weatherly, 2000). HTAs have contributed significantly to this loop of technology improvement (the TAIL) by developing methods to assess efficacy and efficiency of health technologies. They synthesize information derived from scientific practice for the public policy domain (Drummond

& Weatherly, 2000). However, there is concern that the diffusion of HTAs is slower than optimal.

Health Technology Assessments (HTA) provide an interesting case study into the factors that affect technology diffusion, especially considering the organizational parallels between the medical field and the Department of Defense. Health care policy-makers are roughly equivalent to those in the military services that decide to spend money on certain technologies; the health care researchers are roughly equivalent to the military scientists and engineers who develop and/or refine new technologies to improve operational performance; the medical clinicians are roughly equivalent to the military warfighters—the ultimate technology end-users. As a result, the stakeholders in medical technology diffusion face the same sometimes misaligned incentives that affect stakeholders in DoD's technology diffusion environment.

In health care, the policy-makers' careers are evaluated on their ability to make expedient policy decisions with sometimes insufficient information; researchers are professionally rewarded by publishing their work in reputable journals or securing research funding; clinicians, or practitioners, are the stakeholders that ultimately choose to adopt new practices or use new technologies. Practitioners tend to be risk-averse and resist change until uncertainties are fully resolved. The incentives for each stakeholder group reflect those actions on which its members are ultimately evaluated (either formally or informally by their peers, colleagues or patients). The reward systems of these opposing careers can lead to different decisions regarding HTA implementation because their incentives are not aligned.

The diffusion of HTAs was further resisted at the clinical level due to issues involving control. Clinicians will resist adopting HTA innovations if they perceive a conflict between clinic autonomy and compliance with policies mandated from outside the clinic. The clinicians want to control their practices and procedures, perhaps guarding their sense of ownership. The attempt to rely on HTAs to improve

medical practice may be hindered by concern over potential loss of autonomy at the operational level and by the misaligned incentives among stakeholders (Drummond & Weatherly, 2000).

The QWERTY Keyboard

Perhaps the most infamous story of a market failing to adopt a superior technology is the story of how the QWERTY keyboard emerged as the industry standard, even though it is widely recognized as an inferior keyboard configuration. In fact, economic analysis completed in the 1940s proved that the increased efficiency of switching to a properly arranged keyboard would overcome the necessary retraining costs within 10 days (David, 1986). How did an inefficient technology become the industry standard? The QWERTY case study demonstrates the critical importance of *network externalities* in driving or deterring technology adoption and diffusion. Positive network externalities exist whenever the value of adopting a particular technology increases as the number of other adopters of that particular technology increases. Network externalities can be classified as either indirect or direct, and Figure 4 provides a graphical illustration of each variety.

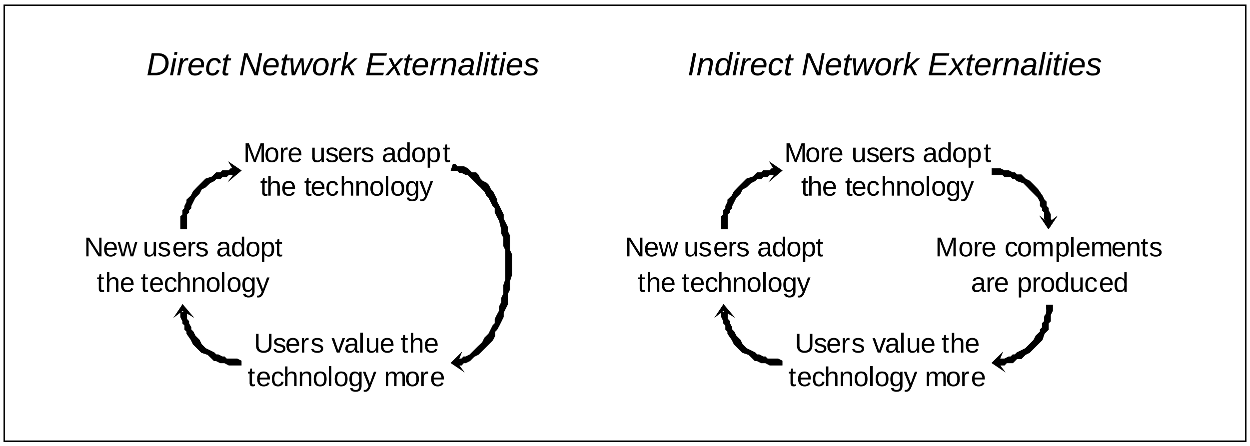

Figure 4. Direct vs. Indirect Network Externalities

The classic example of *direct* network externalities is a telephone network. The value of a telephone network to the first person connected is essentially zero, since there is nobody else in the network with whom to communicate. However, the

value increases for all adopters as more individuals are connected to the network. The telephone example is considered a *direct* network externality because adopter value increases as a direct result of other adopters becoming members of the network. Direct network externalities are sometimes referred to as first-order network externalities.

In some situations, however, there are *indirect* network externalities in which adopter value does not depend directly upon the number of other adopters, but instead increases due to the responses of "complementors" or other players who are influenced by the number of buyers in the network. The classic example of indirect network externalities is the hardware-software relationship in personal computers, video games, or similar technologies: While the value of a particular hardware platform (Macintosh vs. PC, PlayStation vs. Xbox, etc.) in these environments may not depend directly on the number of adopters of that platform, it does depend on the variety of compatible software (applications, games, etc.) that is available for that platform, which turn is directly related to the size of the installed base of users of that platform. Thus, adopter value is indirectly related to the number of other adopters of each competing technology. Such indirect network externalities are also referred to as second-order network externalities, installed base effects or system compatibility effects.

In the competition among typewriter keyboard layouts, the "standards war" was characterized by both direct and indirect network externalities. There was a direct network externality in that users of typewriters wanted to be familiar with whichever keyboard layout was most prevalent, so that their typing skills would be transferrable across typewriters, jobs, locations, and so on. Similarly, businesses wanted to adopt typewriters with whichever keyboard layout was the most common, so that potential employees familiar with that particular layout would be abundant. There was also an indirect network externality present, in that markets for goods and services which complemented specific keyboard layouts developed. For example, the spread of QWERTY keyboards was supported by a country-wide network of

QWERTY typing schools and classes, supporting manuals and handbooks, and QWERTY-based speed-typing competitions (David, 1986).

The QWERTY key arrangement dates back to the 1870s and stems from the age of typewriters—when the keys were purposefully arranged to slow typists down and prevent the typebars (the arms holding the letter stamps) from physically jamming inside the machine. The keys on the center row of the QWERTY keyboard are only used 51% of the time, making the finger activity of the QWERTY typist relatively inefficient. In contrast, the British-developed keyboard arrangement placed 91% of the most frequently used English language letters in the center row (David, 1986).

By the 1870s, typewriter engineering improvements had rendered obsolete the QWERTY keyboard arrangement justifications. In the ensuing typewriter boom of the 1880s, businesses eager to capture market share produced competing typewriter versions with alternative key arrangements. By 1896, the US typewriter market seemed to be selecting the QWERTY keyboard as the industry standard due to the widely distributed QWERTY models from Sholes-Remington and James Bartlett Hammond.

Essentially, the QWERTY keyboard was initially "superior" in the sense that it reduced the occurrence of typewriter jams, thus promulgating this keyboard arrangement as the dominant standard. Eventually, however, the issue of typewriter jams became less important and the QWERTY keyboard became an inferior standard by the now more-important measure of typing speed and efficiency. By that time, however, the strong direct and indirect network externalities resulting from the large installed-base of QWERTY keyboards insured that this inferior arrangement would remain the dominant standard.

Radio Frequency Identification (RFID)

Passive Radio Frequency Identification (pRFID) has incredible potential to increase supply-chain efficiency. While the adoption and diffusion of this technology

is an ongoing process, RFID technology provides a good lens through which to discuss indirect network externalities. It also illustrates the importance of a respected technology champion when coordination is required across technology adoption stakeholders. This case study examines Wal-Mart's civilian-market RFID technology-adoption initiatives.

Wal-Mart initiated an aggressive RFID adoption strategy in 2005, involving the company's own infrastructure, its top 100 suppliers and a timeline for RFID manufacturers. Wal-Mart's widely publicized implementation plan served as a coordinating mechanism for other retail businesses. Other firms, including Target, could leverage Wal-Mart's bold move to capture the perceived benefits associated with early adoption (Dew & Read, 2007; McWilliams, 2007).

Like the QWERTY keyboard, RFID is a technology characterized by network externalities: its value for each individual user increases with the installed user base. In order to improve performance (product visibility) throughout the network (the supply chain, in this case), as many participants in the network as possible must adopt the technology (RFID). There is an extensive set of complementary hardware and software tools required to exploit RFID in managing the supply chain: retailers must imbed saleable products with pRFID tags; hardware is required to read the integrated tags along the supply chain; and middleware or software is needed to track and process the data collected.

These required complementary hardware and software tools (including humanware—the change of policies and practices) introduce an indirect network externality into the RFID technology adoption process. At the extreme, the indirect network externality takes on the properties of a "weakest link" scenario: The network is only as strong as its weakest link. Without the readers, RFID technology is useless; without the software to process the collected data, the technology is useless; if Wal-Mart employees don't change their policies and practices to exploit the processed data, the technology is useless. RFID needs all of these

complementary developments and participation by all stakeholders throughout the supply chain to maintain product visibility across the supply chain.

Once readers, middleware and procedures are in place, the incremental or variable costs of the passive RFID tags themselves is relatively manageable. The potential gain from real-time information about the status of the supply chain is significant. For example, the ability to react quickly to demand changes for faddish merchandise or seasonal items can significantly reduce Wal-Mart's costs and improve its bottom line.

Wal-Mart has leveraged its position as a market leader to coordinate private-sector RFID adoption. Sam Walton's involvement provided a clear management commitment within Wal-Mart; indeed, he can be considered the reputable and highly visible RFID technology champion within the retail industry. His involvement (through the industry giant he represents) has championed RFID technology and hastened its adoption both within his empire and among his various merchandise suppliers.

To indicate its support for RFID technology, Wal-Mart invited its 100 top suppliers to an RFID conference where it mandated that they would implement RFID technology and its infrastructure if they wanted to continue business relations with Wal-Mart. Not only did Wal-Mart's top suppliers comply with the industry giant's mandate, but 46 additional firms coordinated their adoption of RFID around Wal-Mart's move (Dew & Read, 2007).

Wal-Mart also established an aggressive timeline for producing RFID tags and installing reader equipment. This gave RFID tag manufacturers a reliable production schedule. These efforts to coordinate RFID technology adoption in the retail market hastened the diffusion process and made this particular pRFID technology the industry standard. (Dew and Read, 2007).

RFID implementation in supply-chain management illustrates the effects of indirect network externalities as well as the influence of a powerful technology champion on the adoption process. Without the complementary products, users can't realize the benefits of the new technology. Technology champions, when highly respected and suitably visible, can hasten adoption.

Recurring Themes

This research identifies several recurring themes as critically affecting the success of the adoption. We have focused on those themes that are most relevant to the Department of Defense and most likely affected by changes in defense acquisitions policies and procedures. Recall that the relevant issues for the Department of Defense include coordinating technology adoption across a complex set of decentralized stakeholders, including the decision-maker/buyer/end-user, to align their incentives and specifically engaging the end-users to "pull" the new technology over the chasm.

Benefit/cost Uncertainty

If the end-users are uncertain about the technology's costs and benefits, they will be reluctant to adopt the new technology. Early in the adoption process, users are typically uncertain about the innovation's technical performance, cost and diffusion potential. Technical performance affects the innovation's expected benefits; cost uncertainty affects the innovation's expected cost, and diffusion potential affects the innovation's long-term viability. End-users will become more comfortable as other similar users (an appropriate reference group) adopt the technology and accumulate relevant experience. To some extent, this theme is consistent across all of the case studies highlighted above.

Control

An organization increasing efficiency through centralization and standardization often does so at the expense of the individual end-users' control and autonomy. A larger, centrally controlled infrastructure can save time and money for

procurement, training, support costs and maintenance. The total benefits may exceed the total costs for a new innovation, but the end-users often experience costs that exceed their personal benefits because the benefits are siphoned off by the centralized organization. If end-users lose control over their operations/decisions by adopting a new technology and don't recognize any significant benefits in return, they resist adopting that technology. Concern over losing control was evident in both the CASE and HTA examples described above. With CASE, the engineers that managed the company's internal software were concerned about losing autonomy over this process; with HTA, clinicians were concerned that relying on HTAs to improve medical practice would reduce their autonomy in treating their patients. Successful technology adoption requires thorough demonstration that the benefits from the new technology exceed any drawbacks from its adoption.

Misaligned Incentives

Decision-making within large organizations is frequently compromised by misaligned incentives: individual decision-makers face different incentives and frequently hold goals and objectives divergent from the larger organization. Misaligned organizational incentives are often referred to as the principal-agent problem; generally speaking, individual decision-makers don't directly face the same mission and pressures as the broader organization. The organization's total benefits from adopting a new technology might exceed the organization's total costs; however, misaligned incentives could inhibit the end-user from making the organizationally optimal decision when he/she is acting as the decision-maker. Both the CASE and HTAs programs were inhibited by misaligned incentives. RFID would likely be a similar example if the Wal-Mart had not mandated the change; it would not be in the self-interest of the individual decision-makers to independently adopt RFID without a central mandate requiring all to participate.

Management Commitment

If the end-user within an organization is confident that management is committed to the new technology, the end-user will be more willing to adopt the technology. Management commitment will reduce the perceived risks of the benefit/cost uncertainties end-users face when adopting new technologies and will counteract misaligned incentives. End-users will be more likely to accept those risks if management explicitly endorses the new technology. Wal-Mart's management commitment was evident in the RFID case; more explicit management commitment might have facilitated technology adoption for CASE and HTA technologies.

Technology Champion

As management commitment is necessary for complete adoption of a new technology, the end-user will be less hesitant to commit to a new technology if there is a respected and visible technology champion—even when the champion is external to the decision-makers' organization. With a strong technology champion, other end-users are more likely to adopt the innovation, helping to push the technology across the Technology Adoption Chasm. For example, Target and other commercial firms are more likely to adopt RFID technology if they perceive that Wal-Mart is committed to championing the technology. A technology champion can serve as a self-referencing peer group in attracting Early Adopters and in assisting technology to cross the chasm.

Direct and Indirect Network Externalities

Finally, if the benefit from adopting a technology depends – either directly or indirectly – on the number of other adopters of that technology, potential adopters will be hesitant until a sufficiently large overall network or user-base is well assured. This was particularly evident in both the RFID and QWERTY keyboard cases above. With RFID, Wal-Mart's size and decision to commit to early adoption will help establish the network for pRFID. Similarly, the extensive installed base of QWERTY keyboards helped entrench this seemingly inferior technology as the industry standard.

Application to DoD Technology Adoption

Drawing on the discussion above, the question of whether end-user benefits exceed end-user costs for a new technology can be complicated if either the true benefits or costs aren't well known in advance or if all benefits and costs don't accrue to the end-user. Of particular interest in defense technology transfer, the literature review has identified at least two general circumstances in which end-users' decisions might be distorted: (1) in the presence of end-user cost and benefit uncertainty, and (2) when some costs and/or benefits accrue to others beyond the technology adoption decision-maker (when there are external costs and/or benefits).

Benefit/Cost Uncertainty

One factor affecting technology diffusion is uncertainty about the costs and benefits of a new technology. In general, the benefit-cost comparison will be most favorable for higher-valued users, so we would expect higher-valued users to be among the early adopters of a new technology. Benefit-cost comparisons will be less attractive for medium- and lower-valued users, so we would expect them to adopt later in the adoption lifecycle, if at all. When costs and benefits are poorly defined, users may have trouble identifying if they are high-, medium- or low-value users. This might lead to some false starts, with partial adoptions followed by de-adoption, as some users find they were inappropriately optimistic about the technology's net benefits.

Externalities

Many technologies hoping to "cross the chasm" also experience different externalities. An externality is a consequence of an economic decision that imposes a side-effect on others that is not considered by the decision-makers. In technology adoption, externalities occur when the decision-maker does not bear all of the costs associated with technology adoption or capture all of the associated benefits. Two externalities seem particularly relevant to this research: organizational externalities and network externalities (both direct and indirect).

An organizational externality occurs when some adoption costs and/or benefits are absorbed or felt by the greater organization that has implemented the economic decision; these are not directly born by the end-user/decision-maker. A network externality, on the other hand, occurs when the value of the item increases for each individual user as the size of the user-base increases (Katz & Shapiro; 1986; Shy, 2001).

As we have seen, network externalities can be direct or indirect. For direct network externalities, the value of the item for each user depends directly on the size of the user base. Indirect network externalities occur when the value of the item for each user depends on the available complementary goods. The VCR is another example of a technology exhibiting indirect network externalities. In the 1980s, the Beta and VHS VCRs were competing to be the standard video tape format. As the number of VHS players increased, the set of complementary goods available for the VHS VCR also increased (namely, the number of VHS-format tapes), raising the value of the VHS VCR. This arguably contributed to the eventual success of VHS over the allegedly superior Beta format.

In general, the literature themes align well with the application to the defense technology adoption issues identified above, as pictured in Figure 5 below. Clearly, benefit/cost uncertainty is common to both lists. Control, misaligned incentives, and management commitment are essentially manifestations of organizational externalities. They involve situations in which stakeholders within the organization fail to consider all of the cost and/or benefits associated with their technology adoption decisions; the costs and/or benefits they fail to consider accrue to the organization, as opposed to the individual end-user/decision-maker. Technology champion and complementary goods are more closely related to network externalities. They represent situations in which the benefits of technology adoption depend at least partially on adoption decisions made by others. The literature examined appears to validate the relevance of benefit-cost uncertainty, externality,

and network externality as reoccurring issues for technologies as they attempt to cross the Technology Adoption Chasm.

- **Benefit/Cost Uncertainty**
- **Control**
- **Misaligned Incentives**
- **Management Commitment**
- **Technology Champion**
- **Complementary Goods**

- **Benefit/Cost Uncertainty**
- **Externalities**
- **Network Externalities**

Figure 5. DoD Technology Adoption Themes

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Advanced Concept Technology Demonstration (ACTD)/Joint Capability Technology Demonstration (JCTD) Case Studies

The Advanced Concept Technology Demonstration (ACTD) program, which evolved into the Joint Capability Technology demonstration (JCTD) program, exploits commercial off-the-shelf (COTS) technology that has potential applications to joint military operations. The ACTD/JCTD process takes a nominal 2-4 years and involves three players (see Figure 6): the Office of the Secretary of Defense (OSD)-funded scientists and engineers who develop and demonstrate the technology, the service sponsors who buy and support the technology and the Combatant Commands (COCOMS) and warfighters who use the technology. In this process, OSD funds the scientists and engineers to refine the COTS technology for the joint military operations. After a successful Military Utility Assessment (MUA) that demonstrates the technology would benefit the joint warfighter in the field, the OSD tries to enlist a service sponsor to finance the new technology acquisition and provide it to the warfighters within the COCOMS. This hand-off to service sponsors is a difficult pairing, because the ACTD/JCTD technologies were not previously in the service sponsors' funding plans.

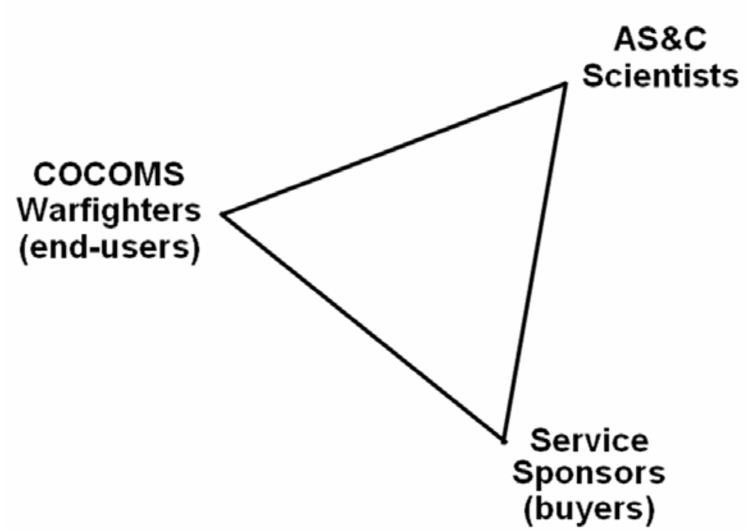

Figure 6. DoD Technology Acquisition Triangle

The ACTD/JCTD program and these emerging technologies have experienced encouraging successes but still face challenges. A service has to sponsor the technology to fund its acquisition and delivery and to sustain it in the field. However, near-term funding resources are typically committed years into the future as the services operate within the planning, programming, budgeting and execution cycle. In addition, the successful fielding of these joint technologies frequently requires coordination across several stakeholders from multiple military services.

Overview of the Empirical Study

As a part of this research, we analyzed the predictive value of ACTD management plans. Our research question was "To what extent can ACTD transition be predicted by data contained in ACTD management plans?" We analyzed the management plans of 38 ACTDs. Of these, 19 were programs that have not transitioned into the acquisition process; these were matched with a sample of 19 programs that are designated as transitioned (the transition to the JCTD program is too recent to be included in this analysis). We then coded several

common variables available in the plans and used multivariate regression to examine what factors predict transition and which did not.

Our results suggest that two variables are significantly correlated with transition in this sample: the level at which the budget and schedule match and the level of technology maturity. These variables emerged as quite strong predictors of transition.

This section of the report proceeds as follows. First, the researchers discuss how we selected, coded and analyzed the data. Second, we discuss the results found. Third, we discuss several interpretations of these results and explain how these findings link to and motivate the technology adoption model developed through this analysis.

Selection, Coding and Data Analysis

ACTDs were first introduced in 1995 with 12 authorized demonstrations. In total, there have been 167 programs approved through FY07. Of these, 112 have completed the demonstration phase (due to the nature of ACTDs, those initiated FY06 or later are typically still underway), and 55 are still in process. Of the 167, 16 programs have been terminated, and three have been place on hold—making a total sample of 19 that have not transitioned. 74 have been placed in the "transitioned on record" category (indicating a successful transition into the acquisition process), while 19 are still in the transition phase. Table 1 rejects this execution history.

Table 1. ACTD Execution History

FY	INITIATED	DEMO COMPLETE	IN DEMO	TERMINATED PRIOR MUA	TERMINATED AFTER MUA	HOLD	TRANSITION ON RECORD	IN TRANSITION
95	11	11		1	1		9	
96	12	12			2		10	
97	9	9					8	1
98	14	14		1	2		11	
99	11	11					11	
00	12	11	1	1	2		8	
01	15	15		1	1		6	7
02	18	15	3	2		1	7	5
03	14	7	7	1		1	2	3
04	13	4	9			1	0	3
05	15	3	12	1			2	0
06	13	0	13				0	0
07	10	0	10				0	0
Total	167	112	55	8	8	3	74	19

For this study, we included all 19 ACTDs that have not transitioned and matched them with a comparison sample of 19 ACTDs that have transitioned. ACTDs used for the comparison sample were selected randomly from ACTDs that entered the program at approximately the same time as the non-transitioning sample. In principle, though the matched sample size is a little small (19), the overall sample size of 38 means that the statistical analysis we performed should provide a reasonably robust test of the factors correlated with transition.

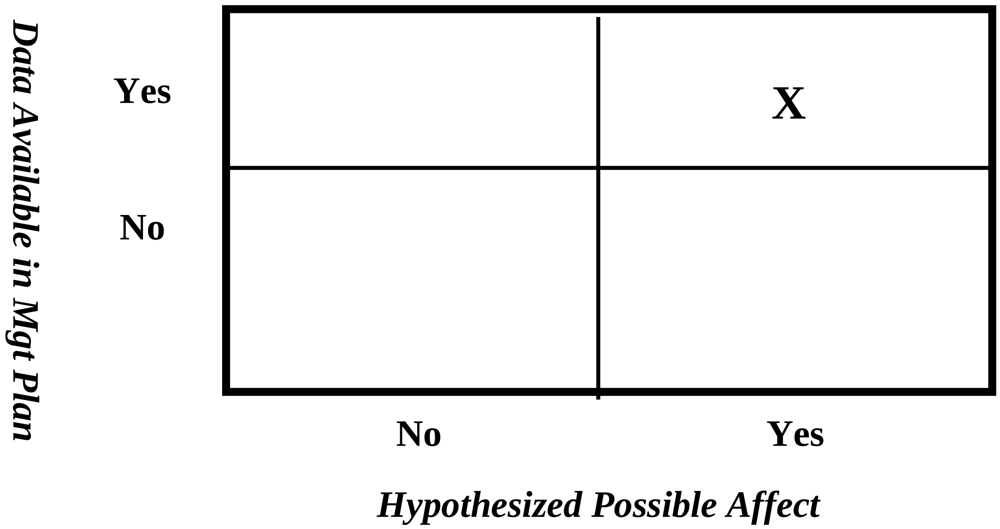

Figure 7. Characterization of Current Data Analysis

Readers of this report should be aware of potential pitfalls of this study that derive from data availability bias. We capture this in Figure 7 (above). First, the study focused on the relationship between data available in management plans and ACTD transition. Needless to say, this is a small subset of the wide variety of other variables that are not expressed in the management plans that might be linked to ACTD transition.

Second, we used our prior knowledge of innovation research to direct the data-gathering exercise from the management plans. We hypothesized certain relationships might be important, and we directed our data-collection efforts based on these hypotheses. We believe we hypothesized a reasonable spectrum of relationships that draw on a variety of innovation research that crosses disciplinary boundaries; i.e., the study is inter-disciplinary (*not* focused purely on economic variables or on organizational variables). However, other researchers might search for and extract different data than we searched and extracted—i.e., search other quadrants of Figure 7. In doing so, they might discover significant relationships that we do not examine in this study.

Data coding

For a full overview of how we coded the data from gathered ACTD management plans, see Phelps and Wideman (2007, pp. 53-60). We coded the following variables:

1. Transition: This was the dependent variable in the study. We coded it as a binary variable, i.e., 0/1.

2. Manager assignment: ACTD guidelines are not explicit but imply all management of individual ACTD programs will be named. We identified seven key roles and counted how many of these were filled with a named manager for each ACTD.

3. Budget Matched to Schedule: We compared the correspondence between schedule and forecasted funding for each ACTD and used a binary coding (i.e., 0/1) to indicate a reasonable match or an obvious mismatch between the development schedule and funding identified in the management plan.

4. Established Military Need: We coded the identification of military needs (high/medium/low) depending on the information expressed in the management plan.

5. Technology Maturity: Given the importance of software in almost all ACTDs, we used a measure of software maturity as a proxy for overall technological maturity. We rated ACTDs high/medium/low depending on the degree of COTS (commercial off-the-shelf) software used.

6. Transition Strategy: We coded transition strategy high/medium/low depending on the degree to which the management plans described a transition strategy for a particular ACTD.

7. Timeline Requirement: We coded the number of years an ACTD was in progress based on a review of the development and demonstration schedules in management plans (NB: ACTD guidelines suggest that programs have a 2-4 schedule).

8. Management plan depth: We used page count as a proxy for the overall comprehensive of the management strategy for an ACTD.

9. Number of Parties Involved: We coded based on the number of parties involved in an ACTD based on parties identified in the management plan.

10. Capital Investment Requirement: This was the total budgeted dollars described in the management plan.

11. Technology Complexity: We coded this high/medium/low based on whether a plan for technical integration was described in the management plan.

12. Risk Assessment: We coded this based on a subjective assessment of program risks and the comprehensiveness of risk-mitigation procedures included in the management plans.

Table 2 (below) exhibits the complete codings we used for the empirical analysis that follows.

Table 2. Raw Data Coding
(Phelps & Wideman, 2007, p. 61)

Program	Dependent Variable	Total Managers Identified	Budget Matches Schedule	Military Need Established	Technology Maturity	Transition Strategy	2-4 Year Requirement	Parties Involved	Technology Complexity	Risk Assessment	Page Count (Plan Depth)	Capital Investment	Management Plan Risk Assessment
Mountain Top	0	4	0	2	3	1	1	3	2	1	22	70.50	1
MDITDS	0	5	1	3	2	3	1	4	2	3	33	12.35	na
Multi Link	0	3	0	1	2	1	1	3	2	2	3	14.70	na
Boost Phase	0	1	0	1	2	2	1	2	1	2	1	0.00	na
CBIS	0	3	0	2	2	3	1	3	2	2	29	0.00	na
Tac Laser	0	1	0	1	1	1	1	2	3	3	2	0.00	na
JMLS	0	6	1	1	3	2	1	4	1	1	21	25.30	1
Tac UAV	0	2	1	2	3	1	1	3	1	1	1	84.90	na
HLS/HLD	0	3	1	1	3	1	0	3	1	1	20	63.43	na
CIA COP	0	3	1	3	2	3	0	3	2	2	51	29.00	2
Agent Defeat	0	1	0	2	3	2	1	1	1	1	13	12.06	na
TACMS-P	0	4	1	2	3	3	1	3	2	1	31	50.6	1
TASC	0	6	1	2	3	1	1	3	3	2	11	2.85	1
HPM	0	0	0	1	1	1	1	0	3	3	0	0	na
Plato	0	0	0	1	1	1	0	0	3	3	0	0	na
HAA	0	3	0	1	2	1	0	5	2	3	3	145	na
JEERCE	0	2	0	2	2	2	1	3	3	2	8	14.2	na
IFSAR	0	1	0	2	2	3	0	4	3	3	6	62.3	na
LEWK	0	3	0	3	1	3	0	4	3	3	16	27.95	na
Adv Joint Plan	1	5	1	1	3	1	1	3	1	1	20	32.8	1
HAE UAV	1	6	1	2	2	3	0	4	2	2	28	935.8	na
Nav War	1	7	1	3	3	3	1	3	2	1	28	59.1	na
SAIP	1	5	1	3	3	3	1	4	3	2	29	119.8	na
Joint Cont Stk	1	3	1	3	2	2	1	5	2	2	29	15.6	na
C4I for CW	1	3	1	3	2	2	0	4	3	2	8	21	na
CAESAR	1	1	1	1	3	1	1	1	1	1	1	1	na
JICR	1	4	1	3	2	3	0	4	2	2	26	0.061	2
LOSAT	1	3	1	2	3	3	1	3	2	1	30	176.7	1
WDLN	1	3	1	2	2	1	1	3	2	2	8	31.4	n/a
MANPACK	1	1	1	2	2	3	1	4	2	2	18	56.5	2
TSV	1	7	1	3	2	2	1	3	2	1	25	143.8	1
JBFSA	1	6	1	3	2	3	1	3	2	2	81	39.75	2
LASER	1	3	1	3	2	3	0	3	2	2	37	33.8	2
JDSR	1	7	1	3	2	3	0	10	2	1	61	31.6	2
CASPOD	1	4	1	2	2	3	0	3	2	2	32	43	2
TIPS	1	3	1	2	2	1	0	3	1	1	13	16.7	2
JAC	1	7	1	2	2	3	1	4	2	2	27	12.6	2
ABA	1	3	1	3	2	3	0	3	2	2	35	52.9	2

Overall Model Results

We used linear regression to analyze the data in Table 2. The full regression model is shown below in Table 3. From this model, we can see that two variables are significantly correlated with ACTD transition: Budget matches schedule and Technology maturity (with greater than 95% confidence). A third variable, Risk assessment, was marginally significant. The overall model suggests that 40% of the variance in ACTD transition can be explained by variance in the 11 independent variables we coded.

Table 3. Linear Regression Model
(Phelps & Wideman, 2007, p. 62)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.76467
R Square	0.58472
Adjusted R Square	0.40902
Standard Error	0.38953
Observations	38

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	11	5.55483	0.50498	3.32802	0.00571
Residual	26	3.94517	0.15174		
Total	37	9.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.99265	0.63874	1.55407	0.13226	-0.32031	2.30560	-0.32031	2.30560
Budget Matches Schedule	0.72701	0.19680	3.69424	0.00103	0.32249	1.13153	0.32249	1.13153
Technology Maturity	-0.38282	0.17502	-2.18728	0.03791	-0.74258	-0.02306	-0.74258	-0.02306
Risk Assessment	-0.29174	0.17528	-1.66446	0.10803	-0.65202	0.06855	-0.65202	0.06855
Capital Investment	0.00041	0.00048	0.85332	0.40127	-0.00057	0.00138	-0.00057	0.00138
Transition Strategy	0.06007	0.11339	0.52980	0.60074	-0.17300	0.29315	-0.17300	0.29315
Military Need Established	0.07130	0.13854	0.51464	0.61115	-0.21347	0.35607	-0.21347	0.35607
Page Count (Plan Depth)	-0.00289	0.00627	-0.46013	0.64925	-0.01578	0.01001	-0.01578	0.01001
2-4 Year Requirement	0.06853	0.15948	0.42974	0.67092	-0.25928	0.39635	-0.25928	0.39635
Technology Complexity	0.05759	0.14643	0.39328	0.69732	-0.24340	0.35858	-0.24340	0.35858
Total Managers Identified	-0.01249	0.05208	-0.23991	0.81228	-0.11954	0.09455	-0.11954	0.09455
Parties Involved	0.01112	0.05353	0.20774	0.83705	-0.09892	0.12116	-0.09892	0.12116

Variables Significantly Correlated with ACTD Transition

Based on our analysis in Table 3, we eliminated non-significant variables and ran a more parsimonious analysis that only included three variables: Budget matches schedule, Technology maturity, and Risk assessment. The output of this

linear regression model is shown in Table 4 (below). This model has an adjusted R^2 of 0.50, indicating that half of the variance in ACTD transition is explained by the model. Again, only two variables are significant with 95% confidence: Budget matches schedule and Technology maturity.

Table 4. Linear Regression Model for Significant Variables Only
(Phelps & Wideman, 2007, p. 65)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.73743
R Square	0.54381
Adjusted R Square	0.50355
Standard Error	0.35702
Observations	38

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	5.16616	1.72205	13.50994	0.00001
Residual	34	4.33384	0.12747		
Total	37	9.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.17339	0.55039	2.13191	0.04032	0.05486	2.29192	0.05486	2.29192
Budget Matches Schedule	0.77935	0.14193	5.49106	0.00000	0.49091	1.06779	0.49091	1.06779
Technology Maturity	-0.36725	0.14892	-2.46604	0.01886	-0.66990	-0.06460	-0.66990	-0.06460
Risk Assessment	-0.21433	0.13300	-1.61151	0.11631	-0.48461	0.05596	-0.48461	0.05596

Correlation between Variables

In order to understand the non-significance of the Risk-assessment variable, we analyzed the correlation between independent variables. Table 5 (below) presents these relationships, with the key relationships highlighted in green.

The most important point to note from Table 5 is the positive and strong correlation between Technology maturity and Risk assessment. This analysis, together with the non-significance of Risk assessment (at the 95% confidence level) in the analyses presented in Tables 3 and 4, suggests Risk assessment is strongly related to technology transition; reducing risk could prove beneficial to technologies trying to cross the Chasm.

Table 5. Correlation between Significant Variables
(Phelps & Wideman, 2007, p. 66)

	Total Managers Identified	*Budget Matches Schedule*	*Military Need Established*	*Technology Maturity*	*Transition Strategy*	*2-4 Year Requirement*	*Parties Involved*	*Technology Complexity*	*Risk Assessment*	*Page Count (Plan Depth)*	*Capital Investment*
Total Managers Identified	1										
Budget Matches Schedule	0.55817	1									
Military Need Established	0.43561	0.43503	1								
Technology Maturity	0.32664	**0.41750**	-0.03499	1							
Transition Strategy	0.34858	0.29011	0.66989	-0.05051	1						
2-4 Year Requirement	0.07191	-0.04942	-0.20404	0.35085	-0.19280	1					
Parties Involved	0.54582	0.32021	0.44129	0.05774	0.39214	-0.26816	1				
Technology Complexity	-0.08823	-0.31208	0.25035	-0.52671	0.17046	-0.13318	0.01922	1			
Risk Assessment	-0.35662	**0.47130**	-0.02527	**0.77122**	0.07443	-0.24736	-0.10886	0.67607	1		
Page Count (Plan Depth)	0.59889	0.49521	0.63518	0.09658	0.65794	-0.12157	0.46631	-0.07085	-0.21105	1	
Capital Investment	0.26217	0.16029	0.02544	0.04517	0.18892	-0.20567	0.13642	-0.01376	-0.03373	0.09782	1

Interpreting the Results and Linking Them to the Rest of the Study

In this section of the report, we attempt to move from the empirical results we found to a proposed underlying conceptual model that captures the ACTD transition (or non-transition) phenomenon. We have endeavored to capture the key points in Figure 8 below:

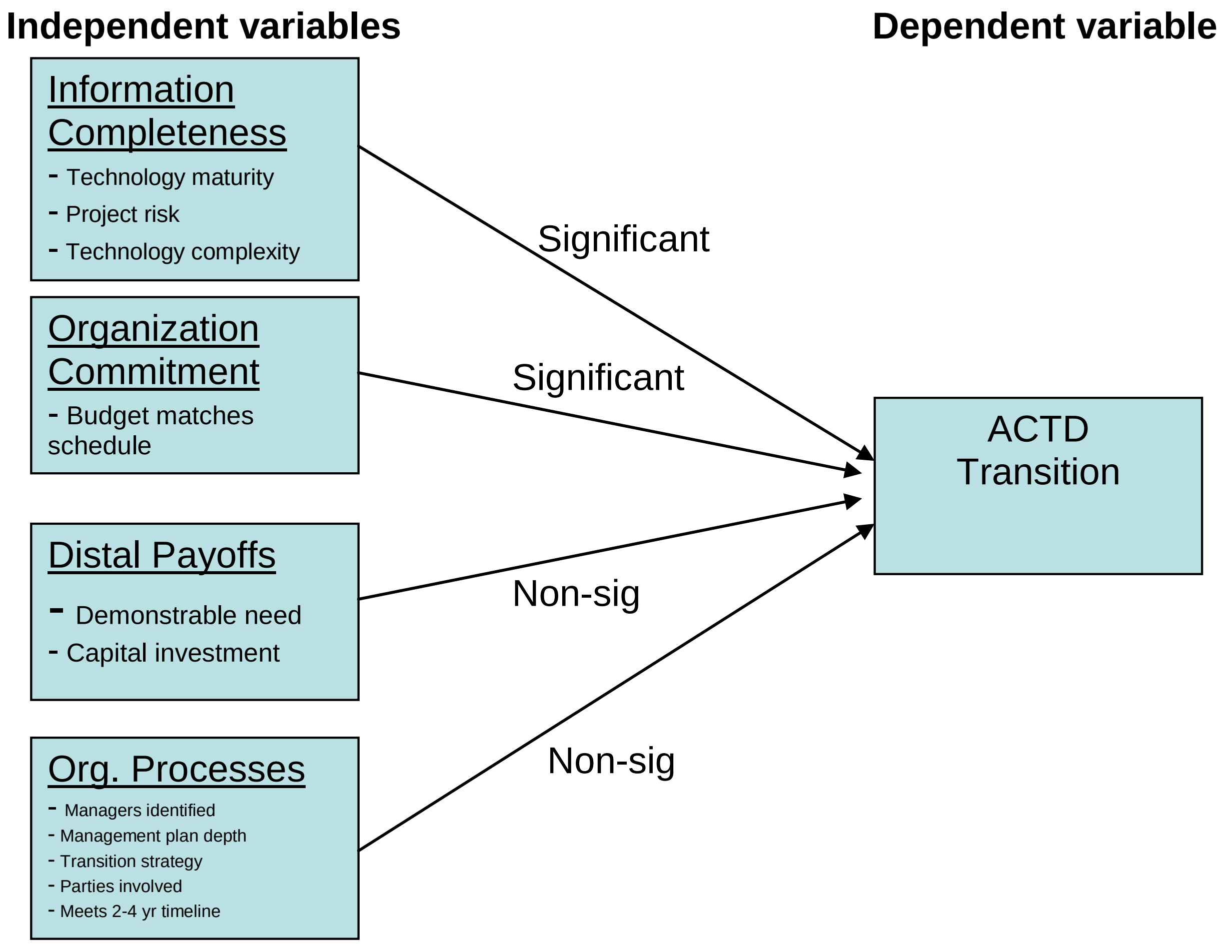

Figure 8. ACTD Management Plan/Transition Model

The suggestion we make in Figure 8 is that the variables we measured in our empirical study are proxies for four underlying factors:

1. Information completeness: A key question in all ACTDs is "Will the technology work?" The more complete the answer to this question, the more likely that an ACTD will transition successfully. More complete answers are possible when there is more information available about the technology; i.e., data that shows it works. In the empirical study, we used three proxies to measure this variable: *technology maturity, project risk* and *technology complexity*. Of these measures, technology maturity turned out to be the significant metric. The intuition here is that more mature technologies are information rich and there is less risk in that information because the technology has been in use longer.

2. Organizational commitment: Another important question for ACTD transition is "Are there DoD entities that are committed to funding it?" We captured the funding concept in our measure *budget matches schedule*, which was significantly correlated with transition. The principle underlying this part of the model is that funding commitments are "where the rubber hits the road." The ability to prioritize needed funding for an ACTD is one of the prime indicators of DoD entities having a serious commitment to an ACTD. Such commitments can be contrasted to "cheap talk" about technologies that ultimately fail to attract funding.

3. Distal payoffs: The concept of distal payoffs refers to the ultimate anticipated future payoffs from transitioning a technology. In principle, this might be calculated by using NPV analysis, payback analysis, etc. In our empirical analysis, we used two proxies to capture the importance of this concept: *demonstrable military need* and *capital investment*. These ought, in theory, to be highly correlated with payoffs. Both turned out to be non-significant. We will discuss why this might be the case in the next section of the paper.

4. Organizational processes: This variable represents the underlying organizational/bureaucratic processes involved in the administration of the ACTD program. The management plans we coded contained several measures that might be proxies for these processes, including the *identification of key staffers*, the *depth of management plans*, the *detail of the transition strategy*, the *number of organizational parties* involved, and whether the technology met the *2-4 year timeline criteria* for ACTDs. None of these measures were significantly correlated with ACTD transition.

Overall, the proxies for information completeness and organizational commitment were found to be significant, strong predictors of transition. Proxies for distal payoffs and organizational processes were found to be insignificant. This suggests that our model can be refined down to two questions that are key predictors of ACTD transition:

1. "Will the technology work?" and

2. "Are there DoD entities that are committed to funding it?"

Why are these the important questions in ACTD transition? One interpretation (albeit simplified, of course) is that the general mission of the ACTD

program is processing technologies, and the primary goal of the program—and its benchmark for success—is getting technologies "out of the door" (i.e., successfully transitioned). Individual management roles are aligned to these organizational imperatives. What are the key factors that enable technologies to be pushed out the door? Not surprisingly, technologies that have the commitment of one or more DoD entities (that are, therefore, willing to "put their money where their mouth is") and that have relatively full information about their performance (and, therefore, are relatively certain prospects when fielded into an operational setting) are prime candidates for transition. If we consider the ACTD office as an organization that manages this pipeline of technologies, and consider its narrow set of goals for moving technologies that come into the program back out again (the processing approach we alluded to earlier), then the importance of these two variables make intuitive sense. They can be thought of as two hurdles that every ACTD program has to be able to get over; programs that don't pass these two tests are very significantly less likely to transition, regardless of other variables that might be cited in their favor.

Connecting our Findings on ACTD Transition to Research on Innovation

The findings we have so far presented make even more sense when they are considered in the context of the very rich empirical and conceptual research on innovation which has become a mainstay of academics over the past 50 years. There are several deep issues that are manifest in the ACTD management process that are worth some careful reflection.

Why Are Distal Payoffs Non-significant?

Historically, there has been a long-running debate among economists on the importance of demand-side and supply-side factors in innovation dynamics (Geroski, 2003). Demand-siders argue that the progress of innovation depends, like everything else in economics, on the payoffs to innovation. This means that entrepreneurial perceptions about emerging customer demands and judgments about willingness-to-pay significantly affect which innovations get funded, developed

and subsequently brought to the market. Supply-siders have argued decisively that however much economists might like to think that this is true; this perspective is simply not borne out by empirical research on innovation (Mowery & Rosenberg, 1979). Instead, they have argued that supply-push factors best explain patterns of evolution in technology systems.

The supply-side arguments have largely won the day in the empirical innovation literature (Geroski, 2003). Understanding this trend helps explain why distal payoffs are non-significant in our ACTD analysis. The crux of supply-siders' argument is that there is so much uncertainty about which innovations might be successful in the marketplace that (discounted) payoffs are poor predictors of the direction of innovation (Rosenberg, 1996). Uncertainty manifests itself in a wide variety of ways and is crucial for understanding how innovation processes work. As a result, payoffs are too distal to make much difference in decisions that need to be made today about which innovations to pursue. This is consistent with our literature survey findings—that benefit-cost uncertainty is a critical factor in the technology-adoption process.

How is this explanation reflected in our ACTD data? First, we must consider capital investment, which was a non-significant predictor of transition. Investment is a crucial driver of net present value, so if ACTDs were transitioned based on payoffs, intuition says that capital investment ought to be significant. However, there are a great many uncertainties about the eventual amount of capital a technology will need to bring it to fruition. Ample evidence exists on cost overruns, which are endemic in innovations. Second, we must consider demonstrable military need. DoD faces further uncertainties in estimating the financial value of new technologies because of the difficulty of translating military effectiveness into measures of financial value. Moreover, it is extremely difficult to predict the eventual timing of military use of an innovation; misestimating the timing of cash flows severely undermines the efficacy of NPV analysis.

In sum, the non-significance of distal payoffs in ACTD transition makes perfect sense in light of the research literature on innovation and is consistent with our previous findings.

Why is Organizational Commitment Significant?

The significant result for our proxy of organizational commitment may be connected to the insignificant results we found for distal payoffs. The "budget matched schedule" variable suggests that programs are significantly more likely to transition if they generate funding to match program scheduling. This finding points to the omnipresent status of an ACTD program's budget for its ultimate success or failure. The proper alignment between a program's schedule and its funding is so essential that aligning schedule and funding can signal organizational commitment to a progressing technology.

Given that we have already ruled out distal technology payoffs to predicting which technologies DoD entities will commit funding, then what does predict the pattern of commitments? One hypothesis maintains that this is a matter of organizational politics (Allison & Zellikow, 1999). In the absence of economic certainties (payoffs), politicking takes over. In this view, organizational commitments (reflected in funding for some programs, but not others) emerges from a complex process of internal politicking between key organizational actors. What matters for a project is that some powerful individual applies his/her personal influence to secure discretionary funding for a new technology. In this sense, the proper alignment of the budget and schedule is a proxy for management commitment within the lead service and for a technology champion by others outside the lead service—both identified as critical factors in the earlier literature survey.

Why are Informational Factors Significant?

Our empirical results indicate that a significant and strong correlation exists between technology maturity and ACTD transition. Maturity is, in large part, driven by the degree to which an ACTD is comprised of COTS (commercial off-the-shelf)

technologies. One interpretation of this result is that it reflects the important role that information about the technology’s performance plays in influencing its transition (consistent with the role of benefit-cost uncertainty in the literature survey). Of course, there is much more information available about a pre-existing (COTS) technology than about one that is currently under development. Moreover, risk assessment was highly correlated with maturity, i.e., the assessed risk that a technology might fail. Interestingly, though technology maturity was a significant variable, technology complexity was not. One reason for this might be derived from the way we coded this variable. An alternative explanation is that complexity is, in fact, not a “show stopper” for transition; even complex technologies transition as long as they are mature and proven.

The deeper issue with regard to the information/technology maturity variable is the extent to which this variable reflects beliefs and expectations held about technology in the broader DoD community. We raise this issue because an ACTD’s transition success does not necessarily mean that the technology will be fully deployed or successful when deployed. Therefore, the idea of COTS technologies may have become so powerful among some DoD communities that a high COTS quotient becomes a right of passage for ACTD transition. If this is the case, then COTS will indeed be a powerful predictor of transition. However, it may not be so highly correlated with successful deployment and use.

This issue raises the question of why people come to confidently hold certain beliefs and expectations. These expectations are commonly acknowledged to significantly affect the diffusion of difficult-to-evaluate technologies (where, given uncertainty of evaluation, adoption is driven by mimicry processes) and those technologies that exhibit network externalities (where expectations about the adoption of others causes self-fulfilling prophecies—see Rolhfs, 2001). Therefore, we have to be mindful of the effects that can be rendered by the popularity of certain ideas, such as the faith placed in COTS technology as a right of passage for ACTDs. How do we know the right technologies are transitioning? If everyone believes

COTS is "the way to go," then the portfolio of ACTD transitions will be made up of technologies with high COTS quotients—not because of the eventual military value, but because of shared beliefs among organizational members.

Why Are Organizational Processes Non-significant?

Results indicating insignificant variables are just as important to this study as the significant results. One has to be careful in interpreting insignificant variables because the insignificance might be generated from one of two sources. First, the variable may be inaccurately measured, in which case the insignificant result masks a relationship which would be significant if accurately measured. Second, insignificance could be a genuine result. For the purposes of this discussion, we will assume the later case.

All of the proxies for organizational processes that we measured were insignificant, indicating that this variable is not a reliable predictor of ACTD transition. We had conjectured that identifying managers by name in the management plan might predict transition success based on the hypothesis that mangers might know something about the quality of an ACTD and avoid getting allocated to projects with poor transition prospects. However, we found this proxy was insignificant. We thought management-plan depth and clarity of transition strategy might indicate the effectiveness of organizational processes for pushing ACTDs through different stages and into transition, but both were insignificant. Timeline requirement, another process variable, was similarly insignificant. The number of parties involved might be conjectured as a proxy for organizational complexity, which again was insignificant.

Overall, the insignificance of these variables are important to note because they suggest that the organizational processes involved in ACTD transition are independent of the transition itself. On the one hand, this is good because it suggests that organizational processes don't bias the ACTD transition process. On the other hand, this finding questions the value added by certain organizational

processes (such as the building of comprehensive management plans) that do not appear to have any significant relationship with the end result: the transition record. On the other hand, with regard to the earlier literature survey results, none of the variables identified earlier in this report were found to be insignificant in the ACTD case studies.

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Technology Adoption Models

Benefit-cost uncertainty, organizational externalities and network externalities are issues that seem particularly relevant to DoD technology adoption from our literature survey. The ACTD case studies highlighted benefit-cost uncertainty, management commitment, the existence of a technology champion and expectations about the prospects for future technology transfer. Benefit-cost uncertainty is clearly common to both lists. As highlighted in the earlier discussion, management commitment and the existence of a technology champion are mechanisms that help address organizational and network externalities; expectations about future adoption prospects are also critical to overcome network externalities. Thus, the four factors identified as significant in the ACTD case studies are consistent with the three factors identified as significant in the literature survey. Equally as important, the ACTD case studies did not identify any of the factors from the literature survey as insignificant.

As a result, we will incorporate the three factors from the literature survey, cost-benefit uncertainties, organizational externalities and network externalities, into models of technology adoption. These are presented to help form a framework for future economic experiments and simulations—in which theoretical issues can be tested in a controlled environment using actual human reaction and then simulated to explore potential policies to foster defense technology adoption. These are stylized graphs and are not drawn to scale. They are introduced to illustrate the basic implications of benefit-cost uncertainty and externalities on defense technology adoption.

Benefit and Cost Uncertainty

Figure 9 represents the most basic economic situation, in which there are no externalities, and the buyer and the end-user are modeled as a single entity. The value of the item is represented on the Y-axis, and the total number of users is

represented on the X-axis. There are three types of users—those who place a high, medium or low value on the technology. Notice that the value to each individual user does not change as the number of users increases. In this illustration, only the high value users find it in their interest to adopt, as their value is greater than the cost of adopting the technology. The total benefits increase as an aggregate of the individual benefits for each user.

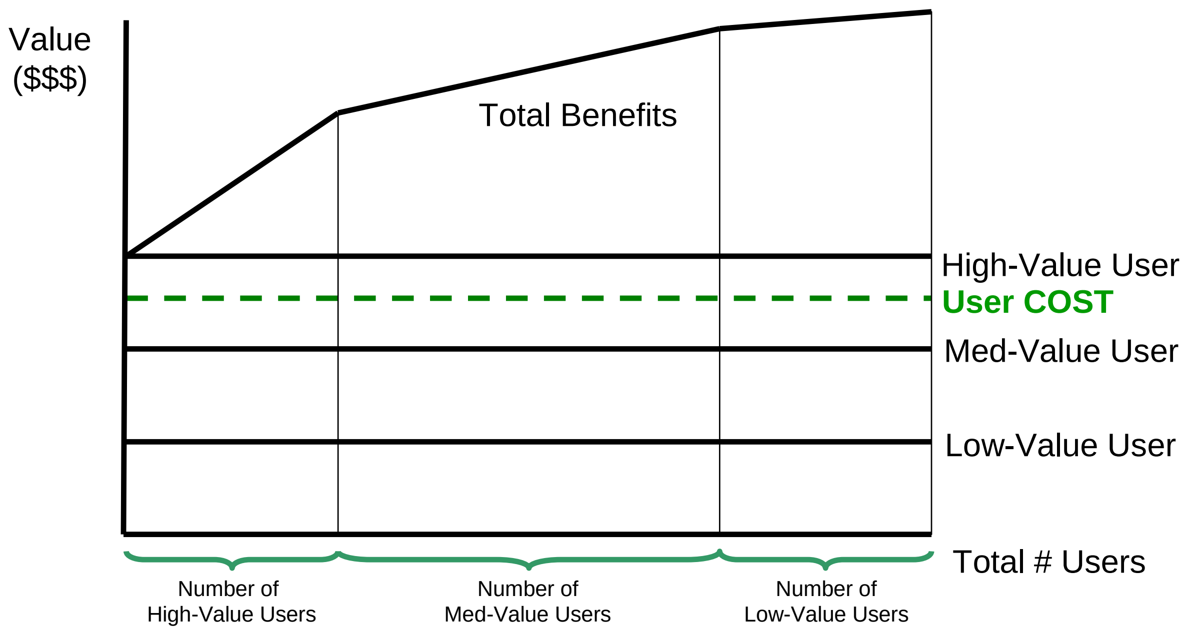

Figure 9. Technology Adoption with Benefit-cost Uncertainty

If users are uncertain about their net benefit, then the graph will illustrate a technology adoption path that mimics that observed in the experiential data. Users may adopt slowly as they attempt to determine what group they are in: high-, medium- or low-valued users. Some medium- and low-value users that misidentify themselves may adopt and then de-adopt; high-value users may transition gradually as they ascertain that they are indeed high-value users.

Organizational Externalities

Figure 10 shows how organizational externalities would affect the total benefits from technology adoption and the expected technology adoption pattern.

Individual users are still characterized as high-, medium- and low-valued users and are uncertain about their identity *ex ante*, as in Figure 9. The total benefits the end-users capture by adopting the new technology is the same as in Figure 9 and depicted by the light grey line in Figure 10. However, organizational or other simple externalities provide benefits to the adopting organization that the end-users don't capture; the total benefit line depicted in Figure 10 aggregates the organizational and individual end-user benefits. These organizational benefits might be savings accruing to the organization through specialization (CASE) or through standardization/improved processes (HTA, RFID).

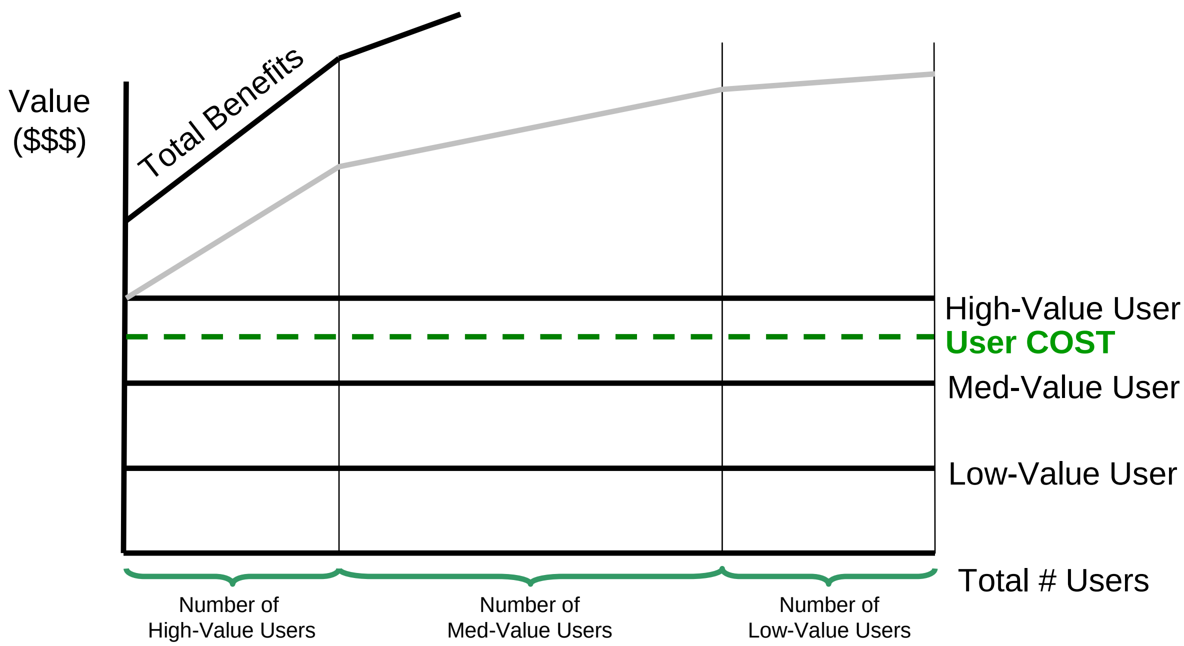

Figure 10. Technology Adoption with Benefit-Cost Uncertainty and Organizational Externalities

With organizational externalities, as pictured above, total benefits might exceed costs for the medium-value users (including the external organizational benefits)—but the individual users' costs might exceed their individual benefits, limiting their incentive to adopt. In this case, the organization needs to consider policies to align the organization's incentives with the individual end-users. For example, the organization might need to subsidize the medium-value users if the

end-users act as profit centers; this would lower their costs below their value, making it in their interest to adopt. For DoD technology adoption in the ACTD/JCTD program, the OSD might need to subsidize technology adoption by the services. Without policies to align organizational and end-user incentives, the organization won't capture the organizational externalities (benefits) associated with technology adoption by intra-marginal groups.

Network Externalities

Figure 11 shows the effects of network externalities. As before, individual users are still characterized as high-, medium- and low-valued users and are uncertain about their identity *ex ante*. However, the end-users' values increase with the number of users in the presence of direct or indirect network externalities. Total benefits are, again, an aggregate of all the individual end-users and increase exponentially in situations with network externalities. In the case illustrated here, high-value users find it in their interest to adopt the technology regardless of how many others have adopted; these end-users represent the Early Market (the Innovators and Early Adopters) in the Technology Adoption Lifecycle.

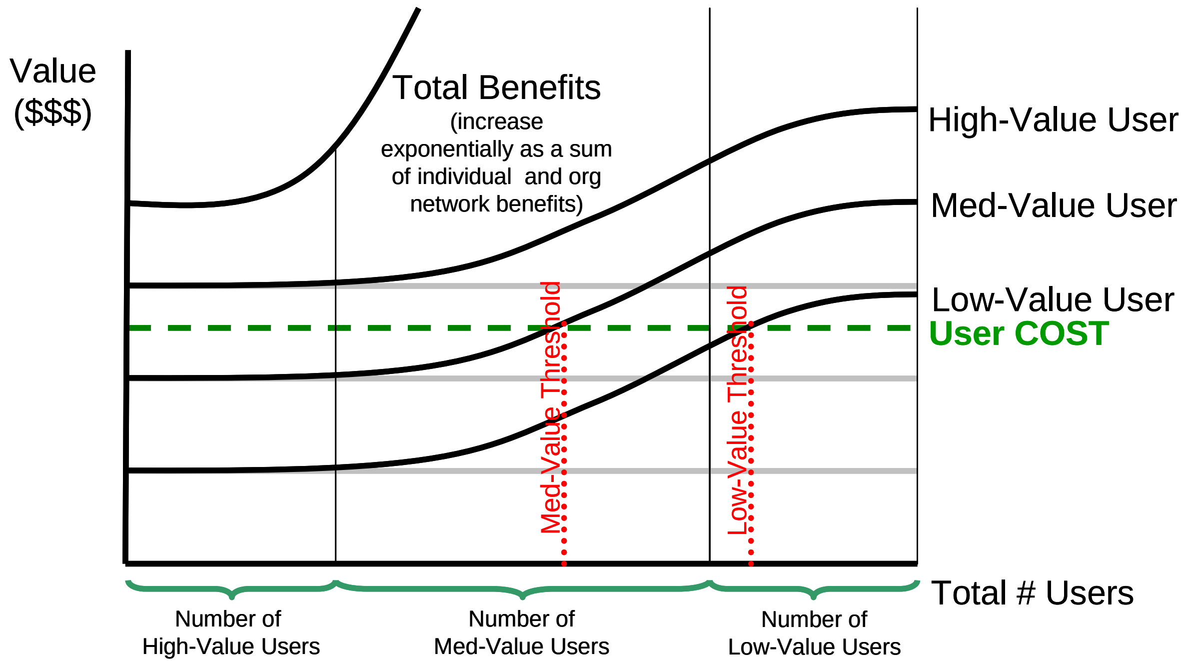

Figure 11. Technology Adoption with Benefit-cost Uncertainty and Network Externalities

The medium-value users would find it in their interest to adopt, but only if there were already a critical mass of users—sufficient enough users that their benefits exceed their costs. These end-users might represent the Early Majority in the Technology Adoption Lifecycle. As a self-referencing group, their adoption decision requires a commitment from an adequate number of their end-user peer group. The Technology Adoption Chasm becomes difficult to cross if the decision to adopt requires a substantial commitment from this class of end-users before their benefits exceed their costs.

The same situation holds for the low-value users in this illustration (the Late Majority and Laggards in the Technology Adoption Lifecycle); they may or may not adopt the new technology, depending on the strength of the network externalities. The issue here is how to coordinate the actions of the medium- and low-value users. It is in best interest of medium-value users to all adopt the new technology, but costs exceed benefits for the early adopters in this group—at least until the number of medium-value users reaches the critical mass. The same holds for the low-value

users. In such cases, the literature emphasizes the value of having a strong management commitment and a clearly identified technology champion to signal an organizational and industry commitment to crossing the Technology Adoption Chasm. For defense technology transfer, this might include a strong OSD/Service Secretary commitment and a clear technology champion within the lead service.

Proposed Experimental Analysis

As stated previously, empirical evidence from both the defense and civilian sectors indicates that technology adoption typically follows one of several different paths: no adoption, complete adoption, partial adoption and partial adoption/de-adoption. No adoption and complete adoption are relatively easy to motivate: costs exceed benefits for either all or none. It is more interesting and difficult to explain partial adoption and de-adoption, particularly cases in which individual end-users partially adopt a new technology while simultaneously supporting the status quo, and cases in which end-users successfully adopt the new technology only to later de-adopt it and return to the status quo. For defense technology, the Navy Marine Corps Intranet (NMCI) is an example of a partially adopted technology that some Navy commands have fully embraced while others continue to support both NMCI and other conventional architectures (GAO, 2006b; Perkins, 2005). The Advanced Technology Ordnance Surveillance (ATOS) system is an example of a technology that was adopted by some users only to be later replaced by the pre-existing status quo barcode tracking system (Doerr, Gates & Mutty, 2006).

After surveying the literature, we identified plausible explanations for these observed technology adoption patterns: benefit-cost uncertainty, organizational and other simple externalities and network externalities. Conceptually, these situations create incentives supporting adoption decisions consistent with the adoption patterns observed in practice—particularly the two intermediate cases: partial adoption and partial adoption/de-adoption.

Unfortunately, we cannot observe incentives in practice—so we can never really be sure why decision-makers choose what they choose to do; we can only observe their actual decisions. To explore whether benefit-cost uncertainty, simple externalities and network externalities can generate the technology adoption patterns observed in practice—particularly partial adoption and de-adoption—we need to observe adoption decisions in a controlled incentive environment; fortunately, we can create this circumstance through an economic experiment (Camerer, 2003).

Experimental Design

An economic experiment artificially constructs and controls incentives and then tracks how experimental subjects behave based on those incentives. Subjects are paid monetary rewards based on the quality of their decisions; these monetary payments are controlled to reflect the incentives being modeled. Experimental results have been found to predict actual decision behavior with reasonable accuracy, so the results are robust and transferable (Davis & Holt, 1993).

Consider the following specification for a technology adoption decision:

$$U_i = p_i(v_i + xq_i) + (1 - p_i)(1 + x(1 - q_i)) + cp_i(1 - p_i)$$

Where:

U_i = utility (profit) for subject i

p_i = proportion of subject i's nodes that have adopted the new technology

v_i = net value of the new technology to actor *i* (the value of the old technology is set to 1)

q_i = proportion of market nodes that have adopted the new technology (excluding subject *i*)

x = strength/value of network externality in the technology application

c = cost of supporting dual technologies within the organization

In this model, U_i is the subject's utility and the metric tracked to determine the subject's monetary earnings. Heterogeneity in value can be introduced by varying v_i across subjects. Cost-benefit uncertainty can be introduced by giving subjects imperfect information about their value of v_i; information about v_i can improve as the experiment progresses. Network externalities can be modified by varying the value of x; there are no network externalities if $x = 0$. This model assumes that the strength of the network externality is the same for all users; this could be changed by indexing x to the individual subject. Finally, the rate of adoption/de-adoption can be limited by limiting the change (positive or negative) in p_i from period to period in the experiment.

To explain the model, the first term in the model, $p_i(v_i + xq_i)$, represents the value of adopting the new technology—including the subject's direct value from the technology and the value captured from any network externalities associated with the new technology for the portion of the industry using the new technology. The second term in the equation, $(1 - p_i)(1 + x(1 - q_i))$, represents the value from the status quo technology, including the subject's direct value from the technology (set to 1) and the value captured from any network externalities associated with this technology for the portion of the industry using the status quo technology. Finally, the third term in the model, $cp_i(1 - p_i)$, measures the cost of supporting two technologies. Notice this term is zero if either $p_i = 1$ or $p_i = 0$; it is maximized when $p_i = 0.5$.

In an experiment using this model, subjects would determine the portion of their capacity to switch to the new technology in each period or switch back to the old technology (the model could also include switching costs if desired). The optimal decision depends on three factors: the subject's value of the new technology, v_i, relative to the old technology (this is not known with certainty at the start of the experiment but can be discerned over time); the strength of the network externality and the portion of the industry switching to the new technology (past industry adoption decisions are known, but the industry adoption decisions for current and

future periods are not); and the cost of maintaining dual technologies. The utility (profit) each subject earns in each period is summed and converted to a monetary payment at the end of the experiment. The experimenter can vary the heterogeneity of costs across subjects, the level of benefit-cost uncertainty, the level of network externalities and the dual-technology maintenance costs. The experiments would verify if the proposed models are likely to generate the technology adoption patterns observed in practice.

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Summary and Issues for Further Research

DoD faces significant challenges as it tries to deliver promising new technologies to service members quickly and cost-effectively. This research examined the Technology Adoption Lifecycle and the Chasm that accompanies it, describing the Technology Adoption Lifecycle in a defense context. Crossing the DoD's Technology Adoption Chasm involves aligning the incentives for each stakeholder in the decision-maker/buyer/end-user chain. To better understand DOD's technology adoption challenges, we reviewed the academic technology diffusion literature to identify the factors associated with successful and unsuccessful technology adoption processes. The literature identified a wide range of factors—many of which were inapplicable to the defense context and others of which, while applicable, provided no normative implications and thus were irrelevant from a policy perspective. The literature review identified six critical factors affecting a technology's ability to cross the defense Technology Adoption Chasm: resolving benefit-cost uncertainty; overcoming concerns about losing decision-making control; correcting misaligned incentives among different stakeholders within the organization; securing management commitment; identifying a clear technology champion; and ensuring that a sufficiently large installed based of users or complementary goods and services will exist.

These six factors were further consolidated into three overarching factors: benefit-cost uncertainty, organizational and other simple externalities, and direct and indirect network externalities. These three factors capture the complexities of the defense technology adoption process that involves multiple decision-makers (the joint staff that determines defense requirements, the service sponsors that manage the acquisition process and influence the resource allocation process, and the end-users or warfighters that actually adopt and use the new technology). Developing technologies clearly involve benefit and cost uncertainties. Organizational externalities arise when there are multiple stakeholders from different constituencies

within DoD. Direct and indirect network externalities reflect the joint nature of many DoD technologies (fully exploiting their potential requires adoption beyond a single service or a single command within a service) and the interrelated nature of defense technologies on the battlefield (most defense technologies require significant complementary support goods and services and must be integrated with other defense technologies).

A closer look at one of DoD's advanced technology development programs, the ACTD/JCTD program, indicated that experience in this program is generally consistent with the factors identified in the literature survey: the importance of benefit-cost uncertainty, management commitment (organizational externalities), technology champion (network externalities) and expectations about the prospects for future technology transfer (network externalities). These were the primary significant variables in these cases, indicating that our literature search focused on the appropriate variables.

The research concluded by presenting conceptual technology adoption models that incorporated benefit-cost uncertainty, organizational externalities and network externalities. These models are capable of explaining the diffusion patterns observed in both the private sector and the defense department: no adoption, full adoption, partial adoption and partial adoption/de-adoption.

What remains to be seen is if decision-makers will actually respond to the incentives in these models in ways that produce the observed adoption patterns. The only means to fully test these models is through an appropriately designed set of economic experiments. An experimental model was described to provide this validation. Future research will conduct the suggested economic experiments. If these models are validated, they will become the foundation for further experiments and simulations to explore policy options the defense department can consider to help defense technologies cross the defense Technology Adoption Chasm.

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Appendix 1. Literature Review

Technology	Locus of Interest	Analysis	Significant Variables	Insignificant Variables
Agriculture				
Apodaca, A. (1967). Corn and custom: The introduction of hybrid corn to Spanish American farmers in New Mexico. In E.H. Spicer (Ed.), *Human problems in technological change* (Case 2, pp. 35-39). New York: John Wiley and Sons.				
Hybrid Corn	Individual Adopter/De-adopter (Farmer)	Case Study	**Reasons for Adoption** Increased Yield	
			Reasons for De-adoption Poor Quality (Taste and Texture)	
Batz, F-J., Peters, K.J., & Janssen, W. (1999). The influence of technology characteristics on the rate and speed of adoption. *Agricultural Economics*, *21(*2), 121-130.				
Modern Dairy Techniques	Technology Characteristics	Econometric	**Dependent Variables = Rate/Speed of Current Adoption** Relative Complexity (-) Relative Risk (-) Relative Investment (-)	
			Dependent Variable = Speed to Completed Adoption Relative Complexity (-)	Relative Risk Relative Investment
Griliches, Z. (1957). Hybrid corn: An exploration in the economics of technological change. *Econometrica*, *25*(4), 501-522.				
Hybrid Corn	Crop Reporting Districts/ States	Econometric	**Dependent Variable = Date of Hybrid Corn Origin Region** Market Density (-) Date of Origin in Immediate Neighborhood (+)	
			Dependent Variable = Rate of Acceptance of Hybrid Corn Average Corn Acre per Farm (+) Ave Diff btwn Hybrid & Traditional Corn Yield (+) Pre-hybrid Average Yield (+)	Standard of Living Importance of Corn as ‘ Crop Total Capital per Farm
			Dependent Variable = Long-run Equilibrium Percentage of Acreage Planted to Hybrid Seed Average Corn Acre per Farm (+) Pre-hybrid Average Yield (+) Total Capital per Farm (+)	Value of Land and Buildings per Farm
Griliches, Z. (1958). Research costs and social returns: Hybrid corn and related innovations. *Journal of Political Economy*, *66*(5), 419-431.				
Hybrid Corn	Adoption Environment Hybrid Corn Market	Cost-benefit Analysis	**Social Rate of Return to Research Investment** Public and Private Research Expenditures - Survey **Increase in Corn Production with Price-change Adjustment - Net Social returns** 5% and 10% discount rate	
Koundouri, P., Nauges, C., & Tzouvelekas, V. (n.d.). *Endogenous technology adoption under production risk: Theory and application to irrigation technology* (Working Paper 0411). University of Crete, Department of Economics. *(Do not quote)*				
Irrigation Technology (Risk Reducing)	Individual Adopter (Farmer)	Econometric	**Dependent Variable = Marginal Contribution of Input to Expected Profit** Variance of Profit (+) Skewness of Profit (-)	
			Dependent Variable = Adoption of Irrigation Technology Age (-) Education (+) Aridity Index (+) Debt (+) Extension Visits (+) Access to Information (+)	Clayey Limestone Soil Marly Limestone Soil Rethymno

			Relative Risk Premium (+) Subsidies (+) Clayey Sandy Soil (+) Chania District (-) Lasithi District (+)
Longo, R.M.J. (1990). Information transfer and the adoption of agricultural innovations. *Journal of the American Society for Information Science*, *41*(1), 1-9.			
Farming Technology (Crop and Animal Husbandry)	Information Source for Technology Individual Adopter (Farmer)	Econometric (Analysis of Variance)	**Dependent Variable = Adoption of Crop Technology** Exposure and Intensity of Mass Media Exposure & Interpersonal '' Communication Source of First Contacts with ' Innovations
			Dependent Variable = Adoption of Animal Husbandry Technology Source of First Contacts with Innovations Exposure and Intensity of Mass Media Exposure & Interpersonal Communication
Mason, R., & Halter, A.N. (1980). Risk attitude and the forced discontinuance of agricultural practices. *Rural Sociology*, *45*(3), 435-447.			
Open Field Burning of Post- Harvest Residue (Grass Seed Crops)	Individual Adopter	Econometric	**Dependent Variable = Decision to Adopt Alternative Practice** Risk Attitude Acres Grass Seed Farmed Farm Income
McNamara, K.T., Wetzstein, M.E., & Douce G.K. (1991). Factors affecting peanut farmer adoption of integrated pest management. *Review of Agricultural Economics*, *13*(1), 129-139.			
Integrated Pest Management	Individual Adopter – Characteristics	Econometric	**Dependent Variable = Decision to Adopt Integrated Pest management Practices** Producer Age Producer Education Percent Farm Income Yield Extension Requests Forward Contracting Extension IPM Hazard Farm Experience Total Income IPM Nonpeanut Crop Nematode Test Literature read Corp Insurance Animal Production Quota Irrigation Percent Peanuts Asset Debt
Oladele, O.I., & Adekoya, A.E. (2006). Implication of farmers' propensity to discontinue adoption of downey-mildew resistant maize and improved cowpea varieties for extension education in Southwestern Nigeria. *The Journal of Agricultural Education and Extension*, *12*(3), 195-200.			
Downy-mildew Resistant Maize Improved Cowpea Varieties	Adoption Environment of Individual De-adopter (Farmer)	Econometric	**Dependent Variable = De-adoption of Maize** Extension Visit to Reinforce Tech Feedback Provision (-) Input Availability (+) Attitude Marketability
			Dependent Variable = De-adoption of Cowpea Attitude (+) Marketability (-) Extension Visit Feedback Provision Input Availability
Price, T.J., Lamb, M.C., & Wetzstein, M.E. (2005). Technology choice under changing peanut policies. *Agricultural Economics*, *33*(1), 11-19.			
Peanut Production Technology (Dryland versus Irrigation)	Peanut Market	Real Options Model	**Dependent Variable = De-adoption of Dryland Production Techniques** Price Support (-) Eliminate Price Support
			Dependent Variable = Adoption of Irrigation Technology Complete Elimination of Price Supports (+)

			Price Supports (-)	
Saha, A., Love, H.A., & Schwart, R. (1994). Adoption of emerging technologies under output uncertainty. *American Journal of Agricultural Economics*, *76*(4), 836-846.				
Bovine Somatotropin (bST)	Individual Adopter (Farmer)	Econometric	**Dependent Variable = Whether Heard of bST**	
			Age (+) Education (+)	Herd Size
			Dependent Variable = Whether to Adopt bST	
			Herd Size (+) Education (+) Experience (-)	Efficiency/Productivity Plans to Expand Prior Experience with Adoption
			Dependent Variable = Intensity of bST Adoption within Herd	
			Herd Size (+) Education (+) Plans to Expand (+) Experience (-) Prior Experience with Adoption (+)	Efficiency/Productivity
Sofranko, A., Swenson B., & Samy, M. (2004). An examination of the extent of innovation discontinuance, the motivations of farmers who discontinue an innovation, and implications for extension. In *AIAEE, Proceedings of the 20th Annual Conference* (pp. 694-705). Dublin, Ireland: AIAEE.				
Value-enhanced Grains	Individual Adopter/De-adopter (Farmer)	Survey	**Reasons to Adopt** Increase Profit (81%) Trial Period (51%) Diversify Farm Ops (39%) Get 1st Hand Experience (37%) Encouraged by Input Suppliers (19%)	**Reasons to De-Adopt** Not Profitable (58%) Difficulty Locating Markets (49%) Inadequate Storage ‘ Facilities (39%) Lacked Technical Information (26%) No Longer Interested (11%)
Health Care				
Drummond, M., & Weatherly, H. (2000). Implementing the findings of health technology assessments: If the CAT got out of the bag, can the TAIL wag the dog? *International Journal of Technology Assessment in Health Care*, *16*(1), 1-12.				
Health Technology Assessments	Individual Non-adopters	Literature Review	**Reasons for Failure to Diffuse**	
			Language barrier Different incentives/perspectives Lack of reliability Lack of consensus Poor timeliness	
Panzano, P.C., & Roth, D. (2006). The decision to adopt evidence-based and other innovative mental health practices: Risky business? *Psychiatric Services*, *57*(8), 1153-1161.				
Mental Health Practices	Individual Adopter (Organization)	Econometric (Baron and Kenny's 4 step approach)	**Dependent Variable = Decision Stage (i.e., Frontrunner, Early Adopters, etc.)**	
			Risk Management Capacity (+)	Risk Propensity
			Dependent Variable = Perceived Risk	
			Risk Management Capacity (-)	
			Dependent Variable = Decision Stage	
			Perceived Risk (-)	
			Dependent Variable = Decision Stage	
			Perceived Risk (-)	Risk-management Capacity
			ANOVA on Dependent Variable = Decision Stage	
			Perceived Risk Experiential Evidence Availability of Dedicated Resources	Scientific Evidence Compatibility Knowledge Set Risk-management ‘ Capacity Ease of Use Risk Propensity Learning Encouragement

				Management's Attitude toward Change
Sheng, O.R.L., Hu, P.J.-H. Wei C.-P., & Ma, P.-C. (1999). Organizational management of telemedicine technology: Conquering time and space boundaries in Health Care services. *IEEE Transactions on Engineering Management*, *26*(3), 265-278.				
Telemedicine	Individual Adopter/De-adopter (Organization)	Conceptual Model	**Reasons to Adopt** Build Service in Core Competence Self-sufficiency Service Financing Change Management Intertechnology Management Budget Timetable	**Reasons to De-Adopt** Immature Technology No Constraints/Priorities No Compatibility with Existing Tech Base No Incentivising Use Lack of Management Commitment
Organization				
Bolton, M.K. (1993). Organizational innovation and substandard performance: When is necessity the mother of innovation. *Organization Science*, *4*(1), 57-75.				
R&D Consortium	Individual De-adopter (Organization)' Individual Consortiums	Econometric	**Dependent Variable = Adoption of MCC** Slack (+)	Performance (Earnings-per-Share) R&D Intensity
			Dependent Variable = Adoption of SPC R&D Intensity (+)	Performance (Earnings/Share) Slack
			Dependent Variable = Adoption of COS R&D Intensity (+)	Performance (Earnings/Share) Slack
			Dependent Variable = Adopters of MCC Performance (Earnings/Share) (+) Slack (-) R&D Intensity (+)	
			Dependent Variable = Adopters of SPC Performance (Earnings/Share) (+) Slack (-) R&D Intensity (+)	
			Dependent Variable = Adopters of COS R&D Intensity (+)	Performance (Earnings/Share) Slack
			Dependent Variable = Early Adopters Performance (Earnings/Share) (-) Slack (+)	R&D Intensity
Burns, L.R., & Wholey, D.R. (1993). Adoption and abandonment of matrix management programs: Effects of organizational characteristics and interorganizational networks. *The Academy of Management Journal*, *36*(1), 106-138.				
Matrix Management Program (Unit Management)	Individual Adopter/De-Adopter (Hospital)	Econometric	**Dependent Variable = Adoption of Unit Management** Outpatient Diversity (+) Teaching Diversity (+) Prestige (+) Reports (+) Regional Force of Adoption (+) Local Force of Adoption (+)	Emergency Diversity Organizational Size Organizational Slack Structural Equivalence Center-Periphery Effect Periphery-Center Effect Time at Risk for Adoption
			Dependent Variable = Early Adoption of Unit Management (1971 or Earlier) Teaching Diversity (+) Organizational Size (+) Prestige (+) Time at Risk for Adoption +)	Emergency Diversity Outpatient Diversity Organizational Slack Reports Regional Force of Adoption Local Force of Adoption

			Dependent Variable = Late Adoption of Unit Management (1972-78)	
			Regional Force of Adoption (+)	Emergency Diversity Outpatient Diversity Teaching Diversity Organizational Size Organizational Slack Prestige Reports Local Force of Adoption Time at Risk for Adoption
			Dependent Variable = Adoption by Nonacceptance Group in Late Period	
			Outpatient Diversity (+) Organizational Size (+) Regional Force of Adoption (+)	Emergency Diversity Teaching Diversity Organizational Slack Prestige Reports Local Force of Adoption Time at Risk for Adoption
			Dependent Variable = Adoption by Acceptance Group in Late Period	
				Emergency Diversity Outpatient Diversity Teaching Diversity Organizational Size Organizational Slack Prestige Reports Regional Force of Adoption Local Force of Adoption Time at Risk for Adoption
			Dependent Variable = De-adoption of Unit Management (1962-78)	
			Outpatient Diversity (-) Regional Force of Adoption (+) Proportional Change in Beds—Prior Year (-)	Emergency Diversity Teaching Diversity Organizational Size Organizational Slack Prestige Reports Local Force of Adoption Change in Outpatient ‘ Diversity—Prior Year Time at Risk for Adoption
Gaba, V. (2006). Learning while innovating: The abandonment of corporate venture capital programs. *Presented at the Smith Entrepreneurship Research Conference.* College Park, MD: Robert H. Smith School of Business.				
Corporate Venture Capital Program	Individual De-adopter (Organization)	Econometric	**Dependent Variable = Probability of De-adoption**	
			Sales (Size) (-) Slack (-) Return on NASDAQ (-) Distance to Silicon Valley (+) Year of Adoption (+) CVC Outcome (-) Internal R&D Outcome (+) Prior De-adopters in Industry (+) Mean Patents Prior De-adopters (+) Prior De-adopters in State (+) Distance*Prior De-adopters in Industry (+)	Age

			Distance*Mean Patents Prior Abandoners (+) Yr of Adoption*Pri Abandoners in Industry (+) Yr of Adopt*Mn Patents Prior Abandoners (+) Year of Adoption*Prior Abandoners in State (+) CVC Outcome*Prior Abandoners in Industry (-) CVC Outcome*Mn Patents Prior Abandoners (-) CVC Outcome*Prior Abandoners in State (-)
Libmann, F. (1990, December). Study on technology transfer databases. *Online Information 90: 14th International Online Information Meeting Proceedings* (pp. 193-204). Oxford: Limited Information.			
Technology Transfer Databases	Technology Characteristics	Literature Survey, Survey, Interviews	**Reasons for Failure to Diffuse** User unfamiliarity & costs to learn technology Lack of informational ads about technology No dominant design or industry standard Lack of complementary services Lack of service support, regular updates, etc. Lack of mrkt seg & targeting by producers Competition Lemons problem
Rao, H., Greve H.R., & Davis, G.F. (2001). Fool's gold: Social proof in the initiation and abandonment of coverage by Wall Street analysts. *Administrative Science Quarterly*, *46*(3), 502-526.			
Coverage of NASDAQ Firms	Individual Adopter/De-adopter (Analyst/Broker) Firm Characteristics Market Environment	Econometric (Cox Model) (Failure-Time)	**Dependent Variable = Adoption** Current Analysts Covering Firm (+) Status of Current Analysts Covering Firm (+) Recent Adoptions (+) Market-adjusted Returns (+) Variance in Returns (-) Institutional Ownership (+) Market Makers for Firm (+) Analysts Covering Industry (+) Average Market Value Status of Recent Adopters Recent De-adoptions Status of Recent De-adopters
			Dependent Variable = Earnings Overestimation Recent Adoptions (+) Status of Recent Adopters (+)
			Dependent Variable = Time to De-adoption Market-adjusted Returns (+) Variance in Returns (-) Market Makers for Firm (-) Current Analysts Covering Firm (+) Status of Recent Adopters (+) Recent Adoptions at Time of Addition (-) Status of Recent Adopters at Addition (-) Earnings Overestimation (-) Recent De-adoptions Status of Recent De-adopters Status of Current Analysts in Firm Recent Adoptions Analysts in Industry Average Market Value Institutional Ownership
Information Technology			
Bayus, B.L., Jain, S., & Rao, A.G. (1997). Too little, too early: Introduction timing and new product performance in the personal digital assistant industry. *Journal of Marketing Research*, *34*(1), 50-63.			
Personal Digital Assistant (PDA)	Market Environment Technology Characteristics (Organization) Project characteristics	Game-Theory Model Case Study	**Reasons for Failure to Diffuse** Overestimated market size Underestimated quality desired Small Market size, product quality and launch timing interrelated to

			Medium to High Benefits	product success
Ewusi-Mensah, K., & Przasnyski, Z.H. (1991). On information systems project abandonment: An exploratory study of organizational practices. *MIS Quarterly*, *15*(1), 67-86.				
Information Systems	Individual De-adopter	Survey	**Abandoned Project Characteristics** Strategically Important Urgently Needed Low to Medium Risk Moderate to Highly Complex Highly Structured Later Stages of Development Multiple Departmental Stakeholders Future Costs Expected to Outweigh Benefits Future Costs Expected to Outweigh Benefits	**Abandoning Organization Characteristics** Disagreement About Project/Politics Management change End-users Resistant to Change Unaligned Incentives **Unimportant Factors** IS Professionals Technology Length to Completion Overall Cost Sunk Costs Sunk Costs
Intrapairot, A.. & Quaddus, M. (1998, July). Adoption and diffusion of data warehousing technology: A systems dynamic approach. In *Proceedings of the 16th international conference of The System Dynamics Society*. Quebec City: System Dynamics Society.				
Data Warehousing Technology	Individual Adopter within Organization (Staff)	Conceptual Model (Multiple Criteria Decision Making)	**Strategies to Successfully Diffuse Technology** Training Support to Affect Attitudes and Vision Cooperation Between IT and Users Increase User Friendliness Top Management Support (Tech Champion) Increased Positive Features of Technology	
Karahanna, E., Straub, D.W., & Chervany, N.L. (1999). Information technology adoption across time: A cross-sectional comparison of pre-adoption and post-adoption beliefs. *MIS Quarterly*, *23*(2), 183-213.				
MS Windows	Individual Adopter within Organization (Staff)	Econometric (Partial Least Squares)	**Dependent Variable = Attitude toward Adopting**	
			Ease of Use (+) Perceived Usefulness (+) Visibility (+) Result Demonstrability (+) Trialability (-)	Image
			Dependent Variable = Subjective Norm toward Adopting	
			Normative Believes x Motivation (NBM) Top Management (+) NBM Supervisor (+) NBM Peers (+) NBM MIS Department (+) NBM Friends (+)	NBM Local Computer Specialists
			Dependent Variable = Behavioral Intention to Adopt	
			Subjective Norm for Adopting (+)	Perceived Voluntariness Attitude toward Adopting
			Dependent Variable = Attitude toward Continuing Use	
			Image (+) Perceived Usefulness (+)	Ease of Use Visibility Result Demonstrability Trialability
			Dependent Variable = Subjective Norm toward Continuing Use	
			Normative Believes x Motivation (NBM) Top Management (+) NBM Supervisor (-) NBM Peers (+) NBM Local Computer Specialist (+)	NBM MIS Department NBM Friends
			Dependent Variable = Behavioral Intention to Continue Using	
			Attitude toward Continuing Use (+)	Subjective Norm toward

			Perceived Voluntariness (-)	Use
Norman, R.J., Corbitt, G.F., Butler, M.C., & McElroy D.D. (1989). CASE technology transfer: A case study of unsuccessful change. *Journal of Systems Management*, *40*(5), 33-37.				
Computer-aided Software Engineering Technology (CASE)	Individual Adopter (Organization)	Case Study	**Reasons for Failed Adoption** Resistance to change High learning curve Lack of visible benefits Lack of communication about industry pressure for implementation Lack of clear and consistent change strategy Lack of CASE champion Perceived lack of management commitment	
Rahim, M.M., Kahn, M.K., & Selamat, M.H. (1987). Adoption versus abandonment of CASE tools: Lessons from two organizations. *Information Technology & People*, *10*(4), 316-329.				
Computer-aided Software Engineering Technology (CASE)	Individual Adopter (Organization)	Case Study	**Reasons for Successful Adoption versus Failed Adoption** Clear goals Structured method already in place Created a selection committee to develop criteria for tool Created a clear/focused implementation plan Extensive communication between users and developers Extensive pilot program Established standard software development methods Reduced the learning curve CASE champion Extensive pre/post training	
Miscellaneous				
David, P.A. (1986). Understanding the economics of QWERTY: The necessity of history. In W.N. Parker (Ed.), *Economic history and the modern economist* (Chapter 4, pp. 30-49). Oxford: Basil Blackwell.				
QWERTY Keyboard	Market Structure	Case Study	**Reasons Why Never De-Adopted** Large, endogenous skilled labor population High switching costs of labor population Economies-of-scale Availability complementary products Technical interrelatedness	
Dew, N., & Read, S. (2007). The more we get together: Coordinating network externality product introduction in the RFID industry. *Technovation*, *27*(10), 569-581.				
RFID	Adoption Environment	Market Structure Literature Survey	**Dependent Variable = Decision to Adopt Subject to Network Externalities** Focal Points Common Knowledge Leadership	
Dewar, R.D., & Dutton, J.E. (1986). The adoption of radical and incremental innovations: An empirical analysis. *Management Science*, *32*(11), 1422-1433.				
Footwear Manufacturing Technology	Individual Adopter (Organization)	Econometric	**Dependent Variable = Adoption** Depth of Knowledge Resources (+) Size (+)	External Exposure Managerial Attitudes Centralization Organizational Complexity
Greve, H.R. (1995). Jumping ship: The diffusion of strategy abandonment. *Administrative Science Quarterly*, *40*(3), 444-473.				
Radio Station Formats	Individual De-Adopter (Organization) Market Structure	Econometric	**Dependent Variable = De-adoption** Sale of the Station (+) Corporation Size (-)	Small Market Other-Format Density

			Abandonment by Corporate Contacts (+) Abandoned by Market Contacts (+)	Same-format Density Market Population Top-10 Market 11-25 Market Abandonment by Direct Competitors
Postrel, S.R. (1990). Competing networks and proprietary standards: The case of quadraphonic sound. *Journal of Industrial Economics*, *39*(2), 169-185.				
Quadraphonic Sound	Market Environment	Conceptual Model	**Reasons for De-Adoption** Retailers' low expectations Low quality of early tech releases Poor quality of early versions Competing versions split installed user base Backwards compatibility Low availability of complementary goods	
Rohlfs, J.H. (2001). Picture phone. In J.H. Rohlfs (Ed.), *Bandwagon effects in high technology* (Chapter 8, pp. 83-90). Cambridge, MA: MIT Press.				
Picturephone	Developers of Technology	Case Study Questionnaire	**Reasons for Failure to Diffuse** Lack of skilled sales techniques Lack of patience for acceptance Benefits not obvious over regular phone Regulatory regime No awareness of start-up problem	
			Possible Solutions Construct self-sufficient user set	

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Appendix 2. Literature Surveyed

	Locus of Interest	Methodology
Agriculture		
Apodaca, A. (1967). Corn and custom: The introduction of hybrid corn to Spanish American farmers in New Mexico. In E.H. Spicer (Ed.), *Human problems in technological change* (Case 2, pp. 35-39). New York: John Wiley and Sons.	Individual Adopter	Case Study
Batz, F-J., Peters, K.J., & Janssen, W. (1999). The influence of technology characteristics on the rate and speed of adoption. *Agricultural Economics*, *21*(2), 121-130.	Technology Characteristics	Econometric
Griliches, Z. (1957). Hybrid corn: An exploration in the economics of technological change. *Econometrica*, *25*(4), 501-522.	Adoption Environment	Econometric
Griliches, Z. (1958). Research costs and social returns: Hybrid corn and related innovations. *Journal of Political Economy*, *66*(5), 419-431.	Adoption Environment	Cost-benefit Analysis
Koundouri, P., Nauges, C., & Tzouvelekas, V. (n.d.). *Endogenous technology adoption under production risk: Theory and application to irrigation technology* (Working Paper 0411). University of Crete, Department of Economics.	Individual Adopter	Econometric
Longo, R.M.J. (1990). Information transfer and the adoption of agricultural innovations. *Journal of the American Society for Information Science*, *41*(1), 1-9.	Individual Adopter—Information Sources	Econometric
Mason, R., & Halter, A.N. (1980). Risk attitude and the forced discontinuance of agricultural practices. *Rural Sociology*, *45*(3), 435-447.	Individual Adopter	Econometric
McNamara, K.T., Wetzstein, M.E., & Douce G.K. (1991). Factors affecting peanut farmer adoption of integrated pest management. *Review of Agricultural Economics*, *13*(1), 129-139.	Individual Adopter—Characteristics	Econometric
Oladele, O.I., & Adekoya, A.E. (2006). Implication of farmers' propensity to discontinue adoption of downey-mildew resistant maize and improved cowpea varieties for extension education in Southwestern Nigeria. *The Journal of Agricultural Education and Extension*, *12*(3), 195-200.	Individual Adopter—Adoption Environment	Econometric
Price, T.J., Lamb, M.C., & Wetzstein, M.E. (2005). Technology choice under changing peanut policies. *Agricultural Economics*, *33*(1), 11-19.	Peanut Market	Real Options Model
Saha, A., Love, H.A., & Schwart, R. (1994). Adoption of emerging technologies under output uncertainty. *American Journal of Agricultural Economics*, *76*(4), 836-846.	Individual Adopter—Characteristics	Econometric

	Locus of Interest	Methodology
Sofranko, A., Swenson B., & Samy, M. (2004). An examination of the extent of innovation discontinuance, the motivations of farmers who discontinue an innovation, and implications for extension. In *AIAEE, Proceedings of the 20th Annual Conference* (pp. 694-705). Dublin, Ireland: AIAEE.	Individual Adopter	Survey
Health Care		
Drummond, M., & Weatherly, H. (2000). Implementing the findings of health technology assessments: If the CAT got out of the bag, can the TAIL wag the dog? *International Journal of Technology Assessment in Health Care*, *16*(1), 1-12.	**Individual Adopter**	**Literature Review**
Panzano, P.C., & Roth, D. (2006). The decision to adopt evidence-based and other innovative mental health practices: Risky business? *Psychiatric Services*, *57*(8), 1153-1161.	Individual Adopter (Organization)	Econometric
Sheng, O.R.L., Hu, P.J.-H. Wei C.-P., & Ma, P.-C. (1999). Organizational management of telemedicine technology: Conquering time and space boundaries in Health Care services. *IEEE Transactions on Engineering Management*, *26*(3), 265-278.	Individual Adopter (Organization)	Conceptual
Organization		
Bolton, M.K. (1993). Organizational innovation and substandard performance: When is necessity the mother of innovation. *Organization Science*, *4*(1), 57-75.	Individual Adopters (Organization/ Consortiums)	Econometric
Burns, L.R., & Wholey, D.R. (1993). Adoption and abandonment of matrix management programs: Effects of organizational characteristics and interorganizational networks. *The Academy of Management Journal*, *36*(1), 106-138.	Individual Adopter (Organization)	Econometric
Gaba, V. (2006). Learning while innovating: The abandonment of corporate venture capital programs. *Presented at the Smith Entrepreneurship Research Conference.* College Park, MD: Robert H. Smith School of Business.	Individual Adopter	Econometric
Libmann, F. (1990, December). Study on technology transfer databases. *Online Information 90: 14th International Online Information Meeting Proceedings* (pp. 193-204). Oxford: Limited Information.	Technology Characteristics	Literature Survey, Survey, Interviews
Rao, H., Greve H.R., & Davis, G.F. (2001). Fool's gold: Social proof in the initiation and abandonment of coverage by Wall Street analysts. *Administrative Science Quarterly*, *46*(3), 502-526.	Individual Adopter—Market Environment, Firm Characteristics	Econometric
Information Technology		
Bayus, B.L., Jain, S., & Rao, A.G. (1997). Too little, too early: Introduction timing and new product performance in the personal digital assistant industry. *Journal of Marketing Research*, *34*(1), 50-63.	Market Environment, Technology Characteristics	Case Study—Game-theoretic Model

	Locus of Interest	Methodology
Ewusi-Mensah, K., & Przasnyski, Z.H. (1991). On information systems project abandonment: An exploratory study of organizational practices. *MIS Quarterly*, 15(1), 67-86.	Individual Adopter (Organization), Technology Characteristics	Survey
Intrapairot, A.. & Quaddus, M. (1998, July). Adoption and diffusion of data warehousing technology: A systems dynamic approach. In *Proceedings of the 16th international conference of The System Dynamics Society.* Quebec City: System Dynamics Society.	Individual Adopter (within Organization)	Conceptual Model (Multiple Criteria Decision-making)
Karahanna, E., Straub, D.W., & Chervany, N.L. (1999). Information technology adoption across time: A cross-sectional comparison of pre-adoption and post-adoption beliefs. *MIS Quarterly*, *23*(2), 183-213.	Individual Adopter (within Organization)	Econometric
Norman, R.J., Corbitt, G.F., Butler, M.C., & McElroy D.D. (1989). CASE technology transfer: A case study of unsuccessful change. *Journal of Systems Management*, *40*(5), 33-37.	**Individual Adopter (Organization)**	**Case Study**
Rahim, M.M., Kahn M.K.,, & Selamat, M.H. (1987). Adoption versus abandonment of CASE tools: Lessons from two organizations. *Information Technology & People*, *10*(4), 316-329.	**Individual Adopter (Organization)**	**Case Study**

Miscellaneous

David, P.A. (1986). Understanding the economics of QWERTY: The necessity of history. In W.N. Parker (Ed.), *Economic history and the modern economist* (Chapter 4, pp. 30-49). Oxford: Basil Blackwell.	**Market Structure**	**Case Study**
Dew, N., & Read, S. (2007). The more we get together: Coordinating network externality product introduction in the RFID industry. *Technovation*, *27*(10), 569-581.	**Adoption Environment**	**Interview Data, Literature Survey**
Dewar, R.D., & Dutton, J.E. (1986). The adoption of radical and incremental innovations: An empirical analysis. *Management Science*, *32*(11), 1422-1433.	Individual Adopter (Organization)	Econometric
Greve, H.R. (1995). Jumping ship: The diffusion of strategy abandonment. *Administrative Science Quarterly*, *40*(3), 444-473.	Individual Adopter (Organization), Market Structure	Econometric
Postrel, S.R. (1990). Competing networks and proprietary standards: The case of quadraphonic sound. *Journal of Industrial Economics*, *39*(2), 169-185.	Market Environment	Conceptual Model
Rohlfs, J.H. (2001). Picture phone. In J.H. Rohlfs (Ed.), *Bandwagon effects in high technology* (Chapter 8, pp. 83-90). Cambridge, MA: MIT Press.	Technology Developers	Case Study, Questionnaire

	Locus of Interest	Methodology
Meta-Analysis		
Camison-Zomoza, C., Lapiedra-Alcami, R. Segarra-Cipres, M. & Boronat-Navaro, M. (2004). A meta-analysis of innovation and organizational size. *Organization Studies*, *25*(3), 331-361.	Organization Size	Meta-analysis
Damanpour, F. (1991). Organizational innovations: A meta-analysis of effects of determinants and moderators. *Academy of Management Journal*, *34*(3), 555-590.	Organizational Factors	Meta-analysis
Meyer, A.D., & Goes, J.B. (1988). Organizational assimilation of innovations: A multilevel contextual analysis. *The Academy of Management Journal*, *31*(4), 897-923.	Technology Characteristics, Environment	Meta-analysis
Tornatzky, L.G., & Klein, K.J. (1982). Innovation characteristics and innovation adoption-implementation: A meta-analysis of findings. *IEEE Transactions on Engineering Management*, *29*(1), 28-45.	Technology Characteristics	Meta-analysis

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- BCA: Contractor vs. Organic Growth

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- USAF IT Commodity Council
- Contractors in 21st Century Combat Zone
- Joint Contingency Contracting
- Navy Contract Writing Guide
- Commodity Sourcing Strategies
- Past Performance in Source Selection
- USMC Contingency Contracting
- Transforming DoD Contract Closeout
- Model for Optimizing Contingency Contracting Planning and Execution

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- RFID (4)
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